ADULT, JUVENILE AND LARVAL FISH POPULATIONS IN THE VICINITY OF THE J. H. CAMPBELL POWER PLANT, EASTERN LAKE MICHIGAN, 1977-1980

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INTRODUCTION

In 1975 Consumers Power Company, Jackson, Michigan began construction of a third unit at the J. H. Campbell Power Plant, Port Sheldon, Michigan. It was decided that the cooling water for this new unit would be drawn from Lake Michigan via an offshore intake pipe with an opening at the 11-m depth contour. The openings leading to the intake pipe were fitted with cylindrical wedge-wire screens with 9.5-mm openings. The number and configuration of screens were designed to supply adequate water for the cooling of Unit 3 while creating a minimal withdrawing current of approximately 0.2 m/s. The former discharge from Units 1 and 2 flowed through a canal opening at the shoreline of Lake Michigan. This scheme was modified in 1979-1980 to an offshore discharge structure which now accommodates the discharge from Units 1, 2 and 3. The number and configuration of diffusers at the end of the discharge pipe were designed to mix discharge water with Lake Michigan ambient water to promote mixing in the vicinity of the discharge structure so the change in water temperature over ambient does not exceed 1.7 C within a 29-hectare surface area (72 acres).

To address environmental concerns, an extensive surveillance study in the area was initiated. Environmental impacts of Units 1 and 2 on the fisheries in the area were addressed in previous reports (Jude et al. 1978, 1979a, 1980, 1981a). Additional reports describing the effects of Units 1 and 2 on the benthos of the area were also published (Winnell and Jude 1979, 1980).

The present report includes data taken during 1977-1980 in Lake Michigan near the Campbell Plant and is intended as a baseline data set against which 1981 operational data (Unit 3) can be compared. The entire 1980 data set was considered preoperational, since Unit 3 was infrequently operated in 1980 following its completion in September.

Our intent in designing the sampling scheme used at the Campbell Plant was to establish a spatial and temporal pattern of gear deployment such that all important species and sizes of fish that inhabit the Campbell Plant area were collected. To this end, we incorporated different gear for both adult and juvenile (seines, trawls, gill nets) and larval fish (pelagic net and sled tows) sampling. We increased the intensity of our sampling of larval fishes during the known spawning time of most abundant species (June, July, August). We also sampled a wide range of areas (beach zone out to 15 m in Lake Michigan) and we sampled during the day and night to obviate net avoidance and to collect day-active and night-active species. Onshore and offshore migrations could also be documented in this manner. In Lake Michigan, the classical treatment vs. reference area experiment was established to assess the future effects of the Unit 1, 2 and 3 discharge at 6 m and the Unit 3 intake at 11 m. A reference 6-m station about 3.1 km south has been fished regularly with surface and bottom gill nets, trawls and larval fish nets. Catches have been compared each year to establish whether differences exist between the two areas so that this station on the south transect can act as a valid control. During 1981, any effects of Unit 3 operation can be documented by comparing catches between the two areas.

From 1977 to 1980, there have been a few minor changes in sampling design. These will be specified in detail in METHODS. Our comparisons among years are thought not to be seriously affected by these changes. This report will focus on the Lake Michigan catches of larval, juvenile and adult fish. We will establish the spatial and temporal variability observed in catches over the 4 yr and document the patterns of spawning, local inshore and offshore movements, migrations (immigration, emigration), nursery areas, effect of physical factors such as water temperature and upwellings on fish behavior and some food eaten by selected species of fish will be discussed. Each major species of fish collected in Lake Michigan during our 1977-1980 studies will be discussed under headings of larvae, certain age-groups (YOY, yearlings, adults) and plant effects. Less abundant species will be discussed in a more general manner with efforts directed at seasonal distribution patterns, sizes collected, sex ratios and any atypical behavior or presence noted.

STUDY AREA

The J. H. Campbell Power Plant is located on the eastern shoreline of Lake Michigan in Port Sheldon Township (T6N, R6W) Ottawa County, Michigan (Fig. 1). Land immediately surrounding the the 3.24-km^2 site is classified as "dune" area and is characterized by high sand dunes and bluffs (U.S. Army Corps of Engineers 1971). Within an 8-km radius of the plant, land is primarily used for agriculture and forestry. The aquatic habitat immediate to the plant exhibits considerable variation.

Situated directly south of the plant is Pigeon Lake, the natural collecting basin for the Pigeon River before it enters Lake Michigan. The drainage area of the Pigeon River (approximately 155 km^2) supplies an average flow of 1.12-1.26 m^3/s to Pigeon Lake (Water Resources Commission 1968). The present Unit 1 and 2 water usage of 18.7 m^3/s for cooling condensers causes the natural flow of Pigeon Lake into Lake Michigan to be redirected through the plant. The balance of the water demand is supplied by Lake Michigan water which is drawn into Pigeon Lake. Outflowing water from Units 1 and 2 is discharged into a canal, which prior to 1979 opened at the shoreline of Lake Michigan approximately 1 km north of the entrance of Lake Michigan into Pigeon Lake (Fig. 1). Two stone jetties (366 m long) were constructed at the entrance of Lake Michigan to Pigeon Lake to maintain a passage from Pigeon Lake to Lake Michigan and thus ensure adequate flow of intake water for Units 1 and 2. A comprehensive ecological study of Pigeon Lake is presented by Jude et al. (1981a).

The Lake Michigan area adjacent to the Campbell Plant receives considerable use as a recreational resource. Many sport fishermen troll for trout and salmon, and perch fishing is popular during the summer. Dipping for smelt occurs during the spring. Sailing, swimming and camping are other common recreational uses of the Lake Michigan shore zone.

Depth contours in the area of the plant run roughly parallel to shore under normal conditions. However, during the study period, construction activities associated with the Unit 3 intake and discharge structures often resulted in abnormal sand bar formations due to extensive displacement of large volumes of sand.

In 1973, construction began on an additional power generating unit (Unit 3) which would be situated adjacent to Units 1 and 2 and utilize a common discharge canal. In order to minimize environmental impact, cooling water for Unit 3 was to be drawn from Lake Michigan via an offshore intake pipe. Construction of this offshore intake pipe was initiated in April, 1978. The intake was to be of a branched arm design using 9.5-mm, wedge-wire screens (see Zeitoun, et al. 1981 and Fig. 2) extending to about the 11-m contour. In addition to intake construction, construction of an offshore discharge, which would accommodate the warmwater discharge of Units 1, 2 and 3, was initiated concurrently.

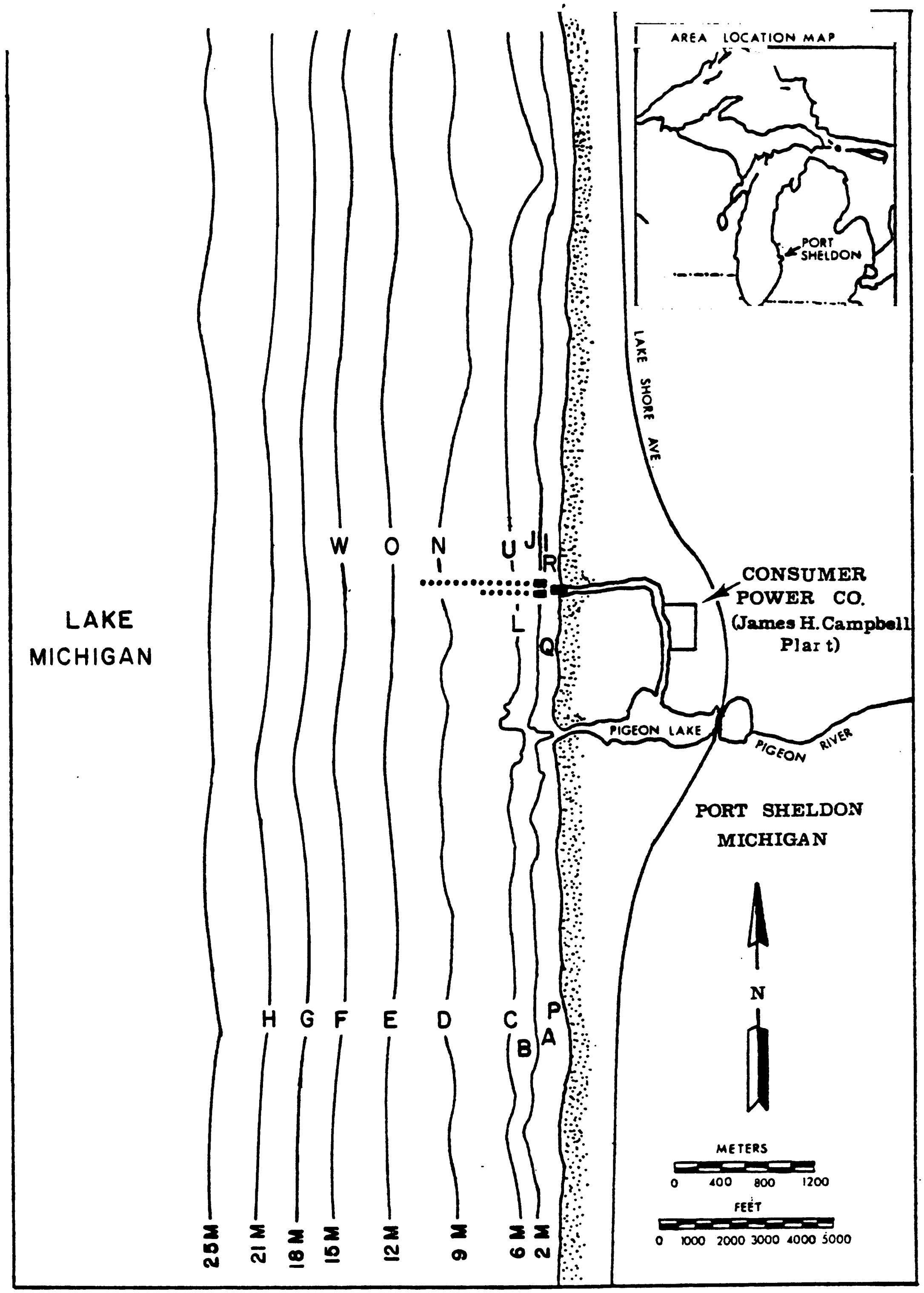


Fig. 1. Scheme of the J. H. Campbell Plant showing Lake Michigan and the 18 sampling stations (A, B, C, D, E, F, G, H, I, J, L, N, O, P, Q, R, U and W) established for fisheries monitoring.

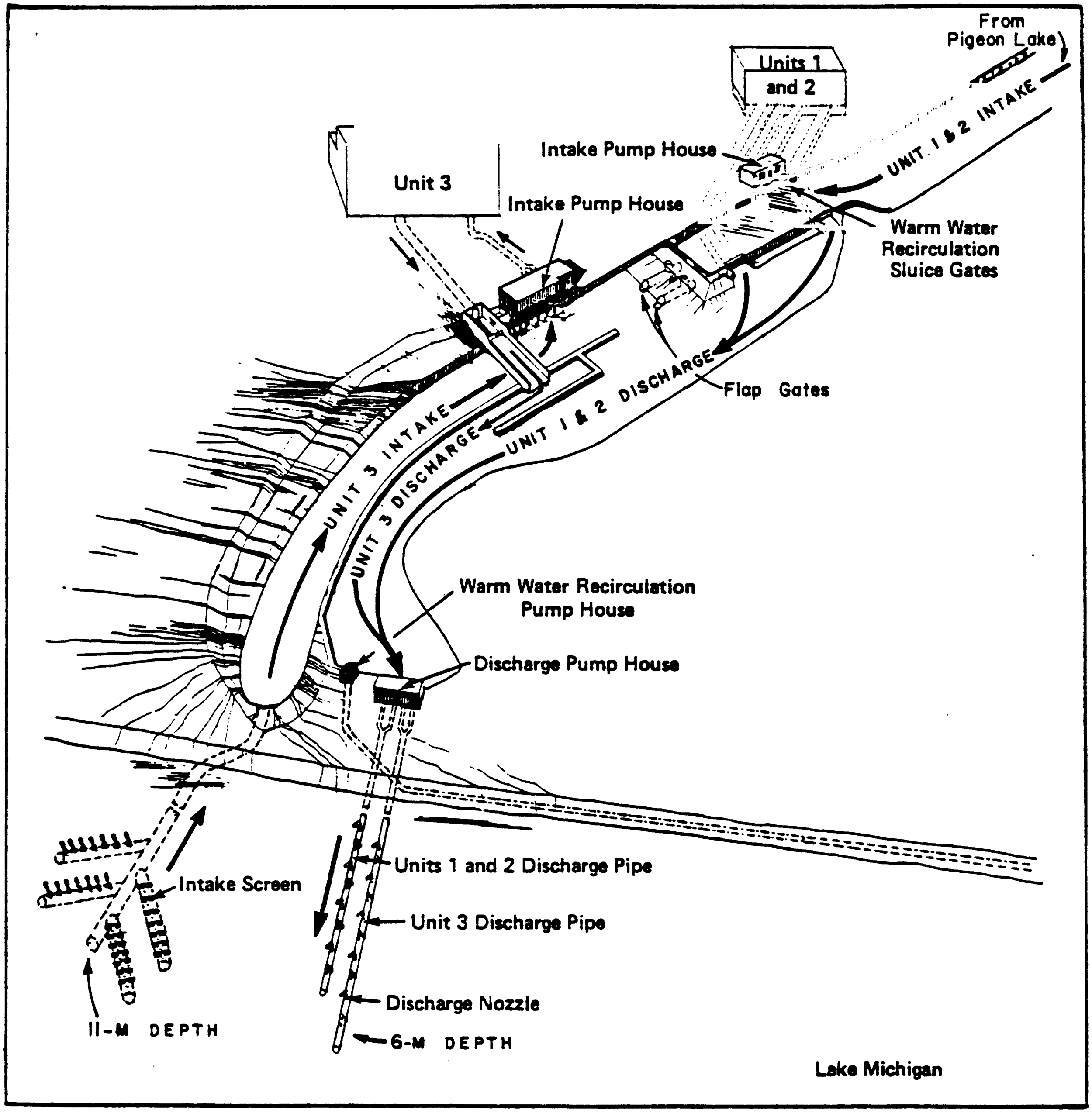


Fig. 2. Scheme of the J. H. Campbell Power Plant showing the various components of the intake and discharge system for Units 1, 2 and 3. Adapted from Randall and Landon (1981).

Water intake and discharge systems and water flow for the Campbell Plant as of 1979 are illustrated in Figure 2. Intake water for Units 1 and 2 continues to be withdrawn from Lake Michigan through Pigeon Lake, while Unit 3 intake water comes from offshore intake structures located at the 11-m depth contour. Cooling water for Unit 3 is gravity fed into the intake canal, and pumped from the canal into Unit 3 condensers. Discharges of all three units are released into a common canal adjacent to the Unit 3 intake canal. Four discharge pumps near the Lake Michigan shoreline pump the combined discharge of Units 1, 2 and 3 offshore in Lake Michigan to the 6-m depth. A variety of bypass mechanisms were incorporated into the entire intake system to provide adequate flow and water levels in the canals, as well as allowing recirculation for prevention of icing.

Stations were established in the area immediate to the past onshore and present offshore discharge (Fig. 1). This transect was chosen to monitor fish distribution in the area affected by the onshore discharge (Units 1 and 2) and potentially affected by the offshore discharge (Units 1, 2 and 3). Stations I, J, L, N, O, U and W (north transect) ranged in depth from 1.5 m at station I to 15 m at station W. Two 6-m stations were chosen at this north transect. Station L (6 m), located approximately 0.3 km south of the Unit 3 discharge, and station U (6 m), approximately 0.3 km north of the discharge, were chosen to aid in monitoring the projected thermal plume and its effect on pelagic fish movement. Station U will be referred to as 6 m, north discharge throughout the text. Station L will be referenced as 6 m, north, except when referring to gill nets when for clarity it will be designated 6 m, south discharge.

Additional stations were chosen at a sequence of depth contours approximately 3.1 km south of the power plant in Lake Michigan (Fig. 1). This reference transect was chosen for its position outside the influence of the present and projected thermal plume and intake channel. Data from these stations are invaluable in describing "normal" trends in fish distribution occurring in Lake Michigan. Stations A - F (south transect) ranged in depth from 1.5 m at station A to 15 m at station F, with intervening stations B, C, D and E separated by 3-m depth intervals.

Of the three Lake Michigan beach stations established, one (station P - Fig. 1) was positioned in the vicinity of the south open water transect (approximately 3.1 km south of the plant) as a reference station in the shoreline area. The two additional stations in the vicinity of the former onshore discharge canal (station Q, approximately 0.6 km south of the discharge and station R, approximately 0.6 km north of the discharge - Fig. 1) aid in monitoring the thermal plume and its effect on shoreline fish movement.

Throughout the study period slight changes in the sampling scheme were initiated to improve the data set in response to changing needs. These changes, along with those alterations in the scheme over the 4 yr imposed by construction activities, are summarized in the METHODS section.

METHODS

INTRODUCTION

Adult and juvenile fish sampling scheme changes at the J. H. Campbell Plant from 1977 to 1980 (Table 1) reflect refinement of our study objectives over the 4 yr to answer additional questions which arose after the initial sampling years. As new information became available regarding placement and configuration of the new offshore intake for Unit 3 and the combined discharge structures for Units 1, 2 and 3, deletion of some stations, which provided more peripheral information, and addition of other stations within the possible zone of influence of the intake and discharge structures became necessary. Throughout the 4 yr, sampling methods and the gear itself remained constant and are described as follows.

SEINING

Seining was performed using a 0.6-cm (0.25 in) mesh nylon seine, 15.2 m x 1.8 m (50 ft x 6 ft) including a 1.8-m (6 ft) bag. The seine was hauled parallel to shore for a distance of 61 m (200 ft). Duplicate non-overlapping hauls were performed both day and night at all seining stations. Monthly seining was performed from April through November (commencing in June 1977) at three beach stations in Lake Michigan (Table 1, Fig. 1). Hauls were performed against the current when possible. During times when waves and current did not permit seining against the current, hauls were made in the direction of the current. Over the 4 yr, sampling stations for seining remained constant. Limnological and physical data (water temperature, secchi disc, wind and wave height) were recorded each time a gear was fished (see Appendixes 2, 3 and 4).

GILLNETTING

Nylon experimental gill nets 36.6 m x 1.8 m (120 ft x 6 ft) were set once a month for approximately 12 h during daylight and 12 h during the night from April to November (commencing in June 1977). Each gill net was composed of 12 panels, each 3 m long, starting with 1.3-cm (0.5 in) bar mesh and proceeding in 0.6-cm (0.25 in) increments up to 7.6-cm (3 in) mesh, with the last panel having 10.2-cm (4 in) mesh. Two of these nets fastened end to end were set together and considered replicates. All gill nets were set parallel to shore. During all 4 yr, bottom gill nets were set at the 1.5-, 3-, 6-, 9- and 12-m depth contours on the reference transect 3.1 km south of the plant (also referred to as the south transect) and at the 6-m depth contour opposite the former onshore discharge canal (Fig. 1). In 1978, this north station (L) was shifted in its designation slightly to the south, but was still within the influence of the thermal plume, while an additional 6-m north station (station U-Fig. 1) was added north of station L in the event that the thermal plume moved north after coming from the discharge. Station L in this report is referred to as 6 m, south discharge and station U is referred to as 6 m, north discharge. Bottom gillnetting at station U (6 m, north discharge) and station N (9-m depth contour, Fig. 1) commenced in 1980 to better document any attraction of fish to the intake and discharge area.

Table 1. Monthly sampling series for juvenile and adult fish at selected stations in Lake Michigan near the J. H. Campbell Plant, Port Sheldon, Michigan. Trawling at station B (3 m) was only done during conditions of reduced wave height.

Station	Maximum Depth (m)	Beach Seining	Surface Gillnetting	Bottom Gillnetting	Bottom Trawling
A	1.5			1977-1980	
B	3.0			1977-1980	1977-1980
C	6.0		1977-1980	1977-1980	1977-1980
D	9.0		Jun-Aug 1977	1977-1980	1977-1980
E	12.0		Jun-Aug 1977	1977-1980	1977-1980
F	15.0				1977-1980
G	18.0				1977 (Day only)
H	21.0				1977 (Day only)
L	6.0		1977-1980	1977-1980	1977-1980
U	6.0		1978-1980	1980	
N	9.0			1980	1978-1980
P	1.5	1977-1980			
Q	1.5	1977-1980			
R	1.5	1977-1980			

Surface gill nets, which are identical to bottom gill nets except for additional floats, were set in all years at the 6-m depth contour at the reference and north transects. In 1978 the previously described station addition (station U, 6 m, north discharge) and modification of the existing 6-m north transect station L were effected to increase surface gill net sampling in the zone of influence of the thermal plume. Additional surface gillnetting was performed at the 9- and 12-m south transect stations only from June to August 1977.

TRAWLING

Bottom trawling was performed using the University of Michigan's R/V Mysis. All trawl hauls were made at an average speed of 4.8 km/h (3 mph). Duplicate 10-min hauls were performed at the 6-, 9-, 12- and 15-m depth contours on a transect 3.1 km south of the plant and at the 6-m depth contour in the vicinity of the new discharge/intake structures at the Campbell Plant. Trawling was performed each year once per month from April to December except in 1977 when trawling commenced in June. In 1977 additional day trawl hauls were performed from June to August at the 18- and 21-m depth contours at the south reference transect. In 1978 a 9-m contour station (station N) was added to the trawling scheme at the north transect to better document the attraction of fish to the intake and discharge area. During all sampling periods, 1977-1980, the 3-m south reference station B was trawled only if diminished wave heights occurred.

A semi-balloon, nylon otter trawl having a 4.9-m (16 ft) headrope and a 5.8-m (19 ft) footrope was used. The body and cod end of the net were composed of 1.9-cm (0.75 in) and 1.6-cm (0.62 in) bar mesh respectively, while the cod end innerliner was 0.63-cm (0.25 in) bar mesh. All trawl hauls were taken parallel to shore following the station depth contour. Two replicate samples were obtained at each station by once trawling south to north and once trawling north to south.

MISSING ADULT AND JUVENILE FISH SAMPLES

While it was hoped that proposed fishing could be performed every month, this was not always possible due to inclement weather, construction activity in the area, or equipment failure. Within reasonable time constraints, effort was made to reschedule sampling which was deleted because of inclement weather. In addition a number of samples over the 4 yr were inadvertently lost before they could be examined. In the case of lost samples, these were carefully reconstructed using field record sheets which were filled out at time of collection. Data from fish collected in the replicate sample could often be used to reconstruct missing length, weight or sexual condition data. Table 2 summarizes all samples of juvenile and adult fish which were missing from our collections during 1977-1980.

FISH LARVAE TOWS

Fish larvae, arbitrarily defined as any fish less than 2.54 cm total length, were collected using a 0.5-m diameter, nylon plankton net of no. 2 mesh (363-micron aperture). A Rigosha flowmeter (Rigosha and Co. Ltd., 10-4 Kajicho 1-Chome, Chiyoda-Ku, Tokyo, 101 Japan) attached to the center opening of the plankton net was used to calculate volume of water sampled. When flowmeters were not available or stopped functioning, average flowmeter values were computed from readings available from the same stations at other times or from stations of comparable depth. Suspect flowmeter readings were changed when accuracy was questionable. All meter revolutions were converted to

Table 2. Summary of juvenile and adult fish samples missing from the proposed monthly sampling series near the J. H. Campbell Power Plant, eastern Lake Michigan 1977-1980. Number of missing observations in parentheses.

Year		Samples Missing
1977	June	All night gill net sets (16)
	August	night surface gill nets at stations C (6 m, south reference) and L (6 m, north discharge) (4)
	October	All day and night gill nets (32)
1978	April	night trawls at station L (6 m, north discharge) (2) day bottom gill net at station A* (1.5 m, south) (1) day surface gill net at U (6 m, north discharge) (2)
	June	night trawl at station N (9 m, north) (1)
	July	day surface gill net at U* (6 m, north discharge) (1) night surface gill net at L (6 m, south discharge) (1)
	August	day trawl at station B (3 m, south) (1)
	October	night trawl at station D* (9 m, south) day seine at station P* (beach - south reference)
	November	day bottom gill nets at stations B* (3 m, south) and E (12 m, south) (2) night surface gill nets at stations C, L and U (all 6 m stations) (6)
1979	November	night surface gill net at station L* (6 m, south discharge) day and night bottom gill net at A (1.5 m, south) (4) day trawl at station B (3 m, south) (2)
1980	July	night bottom gill net at U* (6 m, north discharge)
	September	day and night trawl at B (3 m, south)
	November	night bottom gill nets at A (1.5 m, south), B (3 m, south) and D (9 m, south) (3)

*Samples reconstructed for purposes of analysis.

volume filtered using 1 revolution = 15 liters. Flowmeters were calibrated in a swimming pool by walking a measured distance with a flowmeter attached to a 0.5-m diameter hoop without the net (see Jude et al. 1979b).

Duplicate surface tow samples were collected at the seining stations in Lake Michigan (Fig. 1). Three people simultaneously hand-towed two nets for a distance of approximately 61 m (200 ft) once during the day and once at night. Beach tows were performed twice in June, July and August and once in April, May and September during 1978-1980. In 1977, beach tows were performed twice in June and July (three times at station R in July) and once in August, September, October and November.

Horizontal 5-min fish larvae tows were also performed at discrete depths parallel to shore at 13 stations in Lake Michigan (A, B, C, D, E, F, G, H, I, J, L, N, O) in 1977 (sampling at stations I, J, N and O commenced in July 1977) and 12 stations (A, B, C, D, E, F, I, J, L, N, O, W) from 1978 to 1980. A summary of station depths and sampling strata is presented in Table 3. Sampling was performed both day and night on the same schedule as beach tow samples. Additionally, station L (6 m, south discharge) was sampled three times in July 1977. The series of tows performed in mid-July 1977 at north transect stations by Consumers Power personnel were made at slightly different depth strata compared with our standard series tows.

Table 3. Fish larvae sampling depths (m) from selected stations in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan 1977-1980.

South transect stations	A	B	C	D	E	F	G*	H*	P
North transect stations	I	J	L	N	O	W#			Q, R
Tow depth (m)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
		2.5	2.0	2.5	3.0	4.5	4.0	5.0	
			4.0	4.5	6.0	8.5	9.0	10.0	
			5.5	6.5	9.0	11.5	14.0	15.0	
				8.5	11.0	14.0	17.0	20.0	
Maximum depth (m)	1.5	3.0	6.0	9.0	12.0	15.0	18.0	21.0	

* Stations only sampled during 1977.
# Station added to sampling scheme in 1978-1980.

Larvae tows performed in Lake Michigan at depths of 3 m and less were taken from 6-7-m-long outboard motorboats. The University of Michigan's R/V Mysis was used for tows at deeper stations. For each tow, the procedure was similar and was as follows:

1) Plankton net with attached mason jar and depressor lowered to desired depth (average ship speed: 3-6 km/h or 2-4 mph).
2) Plankton net towed horizontally for 5 min starting at the desired depth which was obtained by measuring cable or rope angle and trigonometrically calculating the amount of cable or rope to be released to reach desired depth.
3) Plankton net hauled to surface and washed using a water hose from the vessel used.
4) Contents rinsed into the wide-mouth glass (0.47 liter) Mason jar, preserved (40 ml of buffered formaldehyde), labeled and sealed.

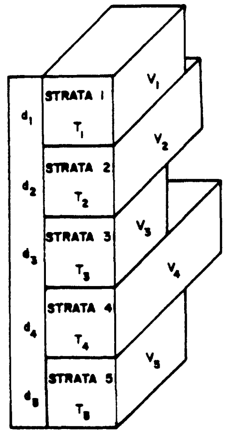
Total numbers of larvae captured in all tows (other than surface tows) were adjusted to compensate for upper strata contamination. The adjustment procedure is outlined in Fig. 3. The method consists of sequential subtraction of numbers of larvae from the lower water depth levels based upon densities observed in upper water strata. We assumed that larvae were homogeneously distributed within a water stratum and that nets passing through a particular stratum from a lower level would catch larvae in proportion to the volume of water filtered. Larvae from all tows conducted below the surface stratum, which were probably caught during the vertical haul following termination of the horizontal tow, were removed via calculation from the final total larvae density presented. We assumed that contamination occurring while lowering the net was negligible. The effect of differential vertical distribution due to larvae size was mitigated by stratifying larvae from each sample into 0.5-mm length intervals. A total of 51 length intervals were defined for fish larvae.

Vertical net hauls, conducted in a 3.6-m-deep swimming pool, were used to estimate the volume of water filtered per meter of vertical tow. Mean volume filtered was 0.48 m^3 (28 $\pm$ 0.52 SE revolutions) yielding a correction factor of 0.18 m^3 water filtered/meter of vertical haul. An example of this adjustment procedure is presented in Table 4.

Length-frequency histograms were prepared for various combinations of the larval fish data. Data were presented as a percentage of the total based on densities. Thus, collection of two larvae of different sizes (n = 2) and presentation of these data would not necessarily yield a histogram showing 50%:50%.

SLED TOWS

Bottom tows were performed with a benthic fish larvae sled equipped with a flowmeter (Yocum and Tesar 1980) (Fig. 4). A single 5-min sled tow was performed once during the day and once at night at all Lake Michigan stations (except beach station R - north discharge) coincident with other fish larvae tows when time and weather permitted. During 1977 only selected stations were sampled, while consistent collection at all stations (except station R)



CALCULATION PROCEDURE:

1. Convert current meter reading to volume filtered (V_i)
2. Stratify total larval (T_i) catch for each sample depth interval into n 0.5-mm length intervals, denoted by $N_{i,m}$.

   Thus, $T_i = \sum_{m=1}^{n} N_{i,m}$
3. Calculate average concentration of larvae of length class m in the first stratum for all m.

   Thus, $\bar{C}_{1,m} = (N_{1,m}/V_1)\ 1000$
4. Begin iterative calculation of adjusted average concentrations of larvae for each depth stratum where

$$\bar{C}_{i,m} = \begin{cases} \dfrac{1000\,(N_{i,m} - \mathrm{trc}\,(0.18(\sum_{j=1}^{i-1} d_j\ \bar{C}_{j,m})/1000)}{V_i - 0.18 \sum_{j=1}^{i-1} d_j} = a \text{ if } a > 0 \\ 0 \quad \text{otherwise} \end{cases}$$

where d_i = vertical depth of water in the i-th water stratum

D = total depth of water column $D = \sum_{i=1}^{5} di$

T_i = total uncorrected catch of larvae in the i-th water stratum.

$N_{i,m}$ = total uncorrected catch of larvae of the m-th size class caught in the i-th water stratum.

V_i = estimates volume of water filtered by net towed in stratum i.

(0.18) = correction factor expressed in terms of volume of water filtered/meter of vertical tow.

i.e.,

$$\text{units} = \frac{m^3}{m} = m^2$$

trc(·) = function which truncates argument to nearest non-negative integer number.

$C_{i,m}$ = adjusted average concentration of larvae of the m-th length class in the j-th depth stratum.

Fig. 3. Schematic representation of adjustment calculations for upper level contamination in larvae samples. Blocks represent varying quantities of water filtered in five different water strata.

Table 4. Example of computational procedures used to correct fish larvae samples for upper level contamination. Refer to Figure 3 for definition of terms. Data values are hypothetical.

Tow depth i (m)	Height of stratum d_i (m)	Volume of water sampled V_i (m^3)	Actual total larvae caught T_i (no.)	Fish larvae length interval m (mm)	Actual number of larvae caught $N_{i,m}$ (no.)	Uncorrected concentration $(N_{i,m}/V_i)\cdot 1000$ (no./1000 m^3)	Corrected concentration $\overline{C}_{i,m}$ (no./1000 m^3)
0	2	30	500	6.6-7.0	200	6666	6666
				10.1-10.5	100	3333	3333
				15.1-15.5	100	3333	3333
				20.6-21.0	100	3333	3333
2	2	25	3	*6.6-7.0	1	40	0
				9.0-9.5	1	40	40
				13.6-14.0	1	40	40
4	2	20	7	7.1-7.5	1	50	51
				8.1-8.5	1	50	51
				*10.1-10.5	2	100	52
				21.1-21.5	1	50	51
				22.0-22.5	2	100	103
6	2	10	12	6.1-6.5	2	200	224
				*6.6-7.0	1	100	0
				*10.1-10.5	3	300	112
				10.6-11.0	2	200	224
				*15.1-15.5	4	400	336
				18.6-19.0	2	200	224
				20.1-20.5	1	100	112

* Adjustment for upper strata contamination performed.

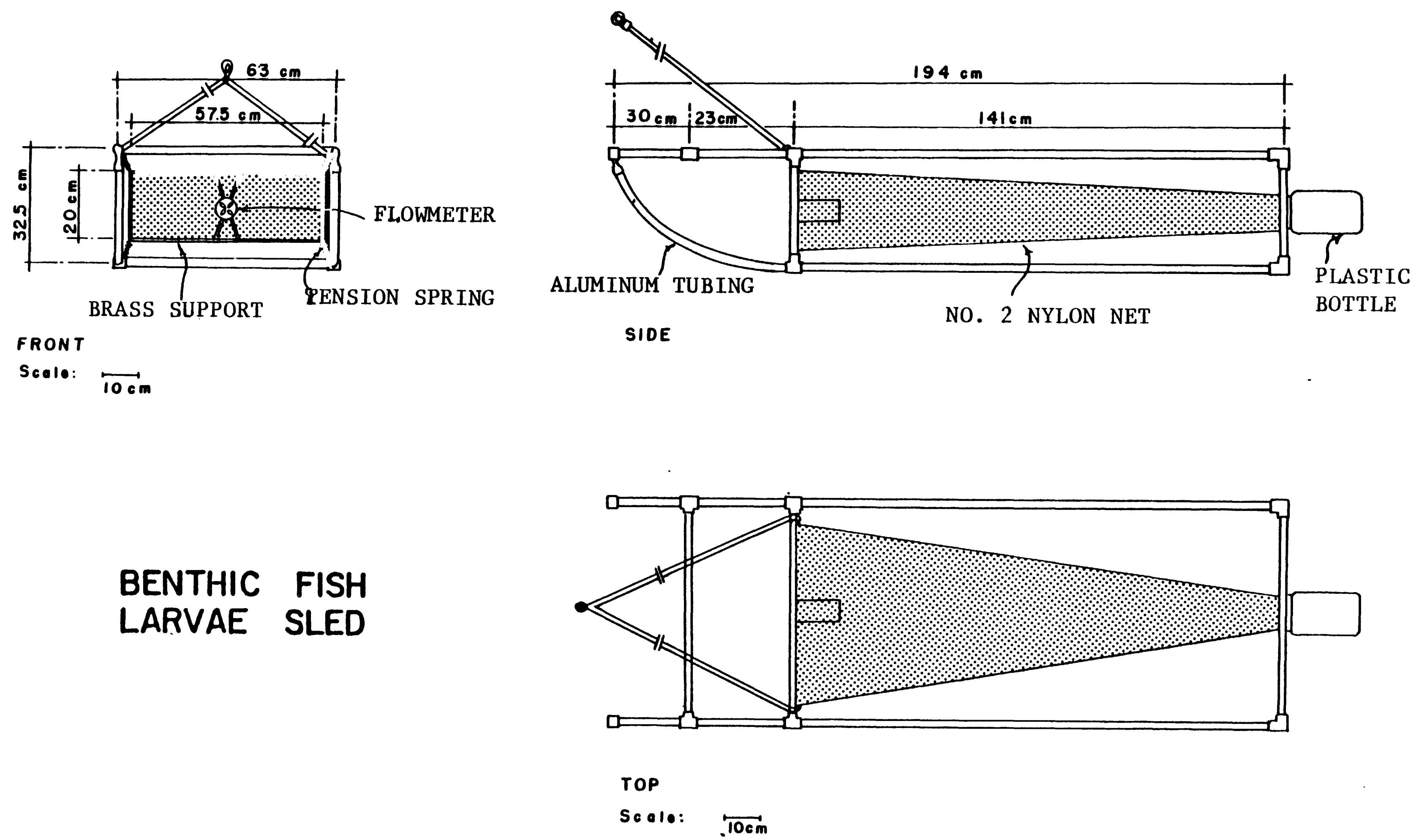


Fig. 4. Benthic fish larvae sled used to collect demersal larval fish. A no. 2, nylon 0.5-m diameter plankton net and Rigosha flowmeter were mounted on the aluminum frame as shown. A pint mason jar, fastened to the net by screwing into a permanently mounted wide mouth jar ring for ease of removal, was inserted into the plastic bottle to prevent damage to the jar.

commenced in 1978. Beginning in May 1979 beach station R (north discharge) was also sampled with a benthic sled. All sled tows were performed from 6-7-m outboard motorboats.

MISSING LARVAL FISH AND EGG SAMPLES

During the study period, fish egg and larval fish samples were occasionally lost because of breakage, inadequate preservation, or inability to collect them due to inclement weather. In the case of beach tows, the replicate was used to estimate the density of larvae in the missing sample. This could not be done for sled tows or larvae tows outside the beach zone. The following is a list of samples which were missing from our standard series due to one of the aforementioned reasons:

1977	22 September night net tows at stations G and H
1978	27 April at station W (4.5 m tow - day) 1 July at station C (4 m tow - night) 2 August at station N (6.5 m tow - night) 14 August at station B (sled tow - night)
1979	15 May at station E (sled tow - night) 15 May at station F (sled tow - night) 15 May at station O (6 m tow - day) 22 August at station A (sled tow - night)
1980	21 April at station A (0.5 m tow - day)

FISH EGG AND LARVAE PROCESSING

Fish eggs and larvae were removed from samples with the aid of a dissecting binocular microscope. In late 1978 a staining technique using Lignin Pink was employed for use with some of the samples difficult to pick because of vast amounts of algae and/or detritus. This stain was used sparingly, but did expedite larval extraction. Larvae samples were first washed with tap water using a screened bucket. Dilute acid was then added and the sample remained in the acid for 45 min. The acid was then rinsed from the sample with tap water and the stain added. After at least 1 h of staining, the sample was rinsed again with tap water and examined. Development and refinement of this technique continued in 1979.

Once larvae were extracted from samples, they were measured to the nearest 0.1 mm (total length), except when samples contained more than 20 larvae of any one species, at which time lengths were determined to the nearest 0.5 mm. Number, species and length of larvae as well as number of eggs found were entered on coding forms and later keypunched to allow for computer data processing. A computer program was developed to adjust numbers of larvae and eggs to number per 1000 m^3 of water filtered using flowmeter readings. (See METHODS - FISH LARVAE TOWS for details).

Knowledge of fish populations and spawning times in southeastern Lake Michigan, specimen comparisons with those stored in the Great Lakes Regional Fish Larvae Collection (Dorr and Jude 1981) and the taxonomic works of Dorr et al. (1976), Hogue et al. (1976), Lippson and Moran (1974), Nelson and Cole (1975) and Jude et al. (1979b) were used in larval fish identifications.

Problem areas exist in some species identifications of larval fish and some identifications were tentative, particularly early in the study. Alewife and gizzard shad could not easily be distinguished from one another from the time of yolk-sac absorption until fin formation had taken place. Separation of longnose and white suckers was also difficult. For a continued description of these problematic areas, see species sections in RESULTS AND DISCUSSION.

Quality Assurance

A quantitative evaluation of the effectiveness of our larval fish processing procedures was conducted. To ensure that larval fish samples were processed efficiently, a quality control program was initiated in 1979 and continued in 1980. A random selection of about 10%, or 212 of the 2231 field samples collected, was conducted and these samples were reprocessed. Techniques were the same as those discussed in FISH EGG AND LARVAE PROCESSING.

Of 101 samples reprocessed in 1979, an average of 11.5% of the larvae in these samples was missed. In 1980 11.1% of the larvae were missed in 111 samples reprocessed. The degree of difficulty in picking through the sample (presence of algae, zooplankton and debris), as well as time of year and thus size of larvae, obviously influenced the percentage of larval fish recovered from samples during the second processing. Lake Michigan samples tended to be filled with small crustaceans, algae and particles of debris. Larvae in these samples were usually small and relatively transparent (e. g. alewife), which made processing difficult. All larvae found during reprocessing were added to the sample totals; no adjustments were made to samples not repicked in the process.

LABORATORY ANALYSIS OF JUVENILE AND ADULT FISH

Each replicate from seine, gill net and trawl catches was labeled and kept separately in plastic bags. Fish were processed fresh when time permitted, or otherwise frozen at the Campbell Plant or on board the R/V Mysis (trawl catches). For laboratory examination, fishes in each bag were thawed, separated by species, then grouped into size classes. When large numbers of a particular size class for an unusually abundant species were present, a subsample was randomly selected from the group and the remaining fish weighed (herein referred to as the mass weight) and discarded. The following data on each fish from the subsample were recorded: total length (to the nearest millimeter, caudal fin pinched), weight (to the nearest 0.1 g using a P1000 Mettler balance), sex, gonad condition, presence or absence of food in the stomach, fin clips, lamprey scars and evidence of diseases and parasites. Identification of food items in piscivorous fish were made when possible. Large fish and fish in the mass weight (over 1000 g) were weighed with a hanging scale spring balance (K023G Chatillon) to the nearest 20 g.

Gonad condition of adult fish was described according to five stages of development: 1) slightly developed, 2) moderately developed - for female, eggs discernible, but not fully ripe, 3) ripe, 4) ripe-running - sex products exiting with application of moderate pressure, 5) spent. Other gonad conditions recorded included: 6) immature, 7) unable to ascertain sex on adult fish, 8) reabsorbed eggs - for female fish, 9) fish decomposed or mutilated so that sex was impossible to determine.

All fish were identified to species using Hubbs and Lagler (1958), Trautman (1957), Scott and Crossman (1973) and Eddy (1957) with the exception of the genus Coregonus (subgenus Leucichthys). Satisfactory keys for this subgenus do not exist because of unsettled questions on the validity of several species (Scott and Crossman 1973) and the possibility of their introgression (Wells and McLain 1973). The only adult Leucichthys that can be positively identified is the lake herring, Coregonus artedii. Other Leucichthys, adult or juvenile, were pooled as unidentified Coregoninae (code XC). These were believed to be mostly bloaters, C. hoyi (see RESULTS AND DISCUSSION, Unidentified Coregoninae).

DATA PROCESSING AND CALCULATIONS

For each adult and juvenile fish examined, the following information was recorded on a 75-column coding form, one fish per line: date and time of sample collection, type of gear, day or night series, station, species code, a unique incrementing number, length, weight, sex, gonad condition and presence or absence of food in the stomach.

Data on subsampled fish were recorded on consecutive lines each having a subsampling code. Special columns were reserved for the corresponding mass weight. Computer programs searched for subsampled lots and calculated number of fish processed, their mean weight and the total number of mass-weighed fish not examined. Mass-weighed fish were proportionally assigned to length intervals based on the number of sampled fish found in each length interval. Fish were divided visually by length into many narrow size classes when originally subsampled to minimize error associated with this reconstruction of sample length frequencies.

Data were keypunched, then read onto computer disks and tapes. For the bulk of our statistical analyses, we used the Michigan Interactive Data Analysis System (MIDAS) which was developed by the Statistical Laboratory of the University of Michigan. From our computer programs, we obtained summary statistics on seasonal gonad condition, temperature-catch relationships, catches by month, gear type, station and day and night series and length-frequency histograms. Most plots used in the report were drawn by the CALCOMP plotter at the University of Michigan Computing Center.

Gill nets were set for as close to 12 h as possible when there was available daylight or darkness. Due to unpredictable weather conditions and changing day length, however, actual time gill nets were fished varied from 4 h 25 min to 15 h 25 min, except for sets in October 1980 when, due to inclement weather, nets were in from 23 h 15 min to 24 h 10 min. Gill net catches for

calculating statistics were adjusted to approximate numbers caught per 12 h by assuming that catch was a linear function of time. The above assumption is not completely valid as gill net catch-per-unit-time might be expected to decrease as the net fills with fish, but increased accuracy could not justify the cost of determining a precise relationship for each species.

DEFINITION OF TERMS

Adult fish length intervals - for figures describing total lengths of adult fish, individuals were assigned to 10-mm intervals. For example, the 30-mm length interval would include fish from 25 to 34 mm. For length-frequency histogram figures for most abundant species, size ranges for adult, yearling and young-of-the-year were determined from length modes of fish collected during each sampling period. Size ranges of each of these groups may be slightly different for different months or years of capture.

Beach zone - refers to that area of water, usually less than 1.5 m, that is accessible to wading during seining and fish larvae sampling activities. Includes only beach stations.

Fish larvae - any fish less than or equal to 25.4 mm in total length.

Fry - any fish greater than 25.4 mm in total length caught in plankton nets. Fish were usually 25.5 to 100 mm.

Inshore - refers to that area of water between the shoreline and 21 m.

Larval fish length intervals - for figures describing total lengths of larval fish, a specimen was assigned to a 0.5-mm interval based on total length. For example, larvae 0.3 mm would be assigned to the interval 0.5 mm (which includes all larvae 0.1 to 0.5 mm), 5.6-mm larvae would be assigned to the interval 6 mm (which encompasses 5.6- to 6.0-mm larvae).

Mature fish - when used in figures, refers to fish which normally would spawn during year of capture.

Nearshore - refers to that area of water less than or equal to 3 m and includes stations P, A, B, Q, R, I and J.

Offshore - term for that area of water, not beach zone, 21 m deep or greater. There are no stations in this zone. Same as deepwater.

Open water - refers to that area of water, which is not beach zone and includes all stations 6 m to 21 m which were usually sampled by boat and which had no aquatic macrophytes present. The area includes stations C, D, E, F, G, H, L, N, O, U and W.

Transition zone - area of water from 1.5 to 3 m.

Zone of influence - that area of Lake Michigan aquatic habitat actually or potentially affected by the presence of the intake and discharge structures of Units 1 and 2 and Unit 3 and their associated withdrawal and discharge of cooling water.

YOY - young-of-the-year - fish in their first year of life. They become yearlings January 1.

Water temperature intervals - catch of adult fish was assigned to 2 C water temperature intervals for the purposes of establishing temperature-catch relationships. For example, the 3 C temperature interval would include fish caught between 2.0 and 3.9 C.

SCUBA OBSERVATIONS

A program of underwater observations has been conducted at the Campbell Plant in Lake Michigan in varying degrees of intensity since 1977. The first survey was performed by J. Dorr in 1977 to ensure the area of the proposed Unit 3 intake and discharge pipeline was not an important spawning site. Details of the study were presented in Jude et al. (1978), but will be briefly restated for completeness.

During 9-10 August 1977, daylight underwater observations were made on seven transects in the vicinity of the J. H. Campbell Plant using SCUBA. Two transects (dives no. 1 and 3) were swum perpendicular to shore between the 6- and 12-m depth contours (Fig. 5). The first transect was offshore from the discharge canal, the second was offshore from the jetties; each transect covered a distance of approximately 1000 m. At the end of each transect a continuing leg was swum perpendicular to the main transect for distances of 400 and 200 m respectively.

A third transect (dive no. 2) was swum at a reference location 3 km south of the plant. This transect was perpendicular to shore, extending from the 10.5-m to 6-m contours, a distance of approximately 800 m. A continuing leg was swum south, parallel to shore along the 6-m contour, for a distance of 400 m. An additional three transects (dives no. 4-6) were swum parallel to shore for a distance of 200 m along either the 9- or 12-m contours. One final transect (dive no. 7) was swum 200 m north along the 12-m contour, then shoreward to the 9-m contour, and then 200 m north along the 9-m contour.

In 1978 and 1979 SCUBA observations were confined to the intake canal. During 1980 a regular diving program was initiated in the area of the new intake and discharge system in Lake Michigan, but because of construction activity, was limited. Visual observations were conducted once per month, July through October 1980 at two specified locations, including two dives in the area of the intake structures (one day, one night), and one day dive at the reference area 3 km south of the plant. Substrates in the reference area were typical of those found in the inshore areas of southeastern Lake Michigan and were comprised of uniform-size, shifting sand presenting a smooth and gently sloping surface profile. The intake station substrate consisted of

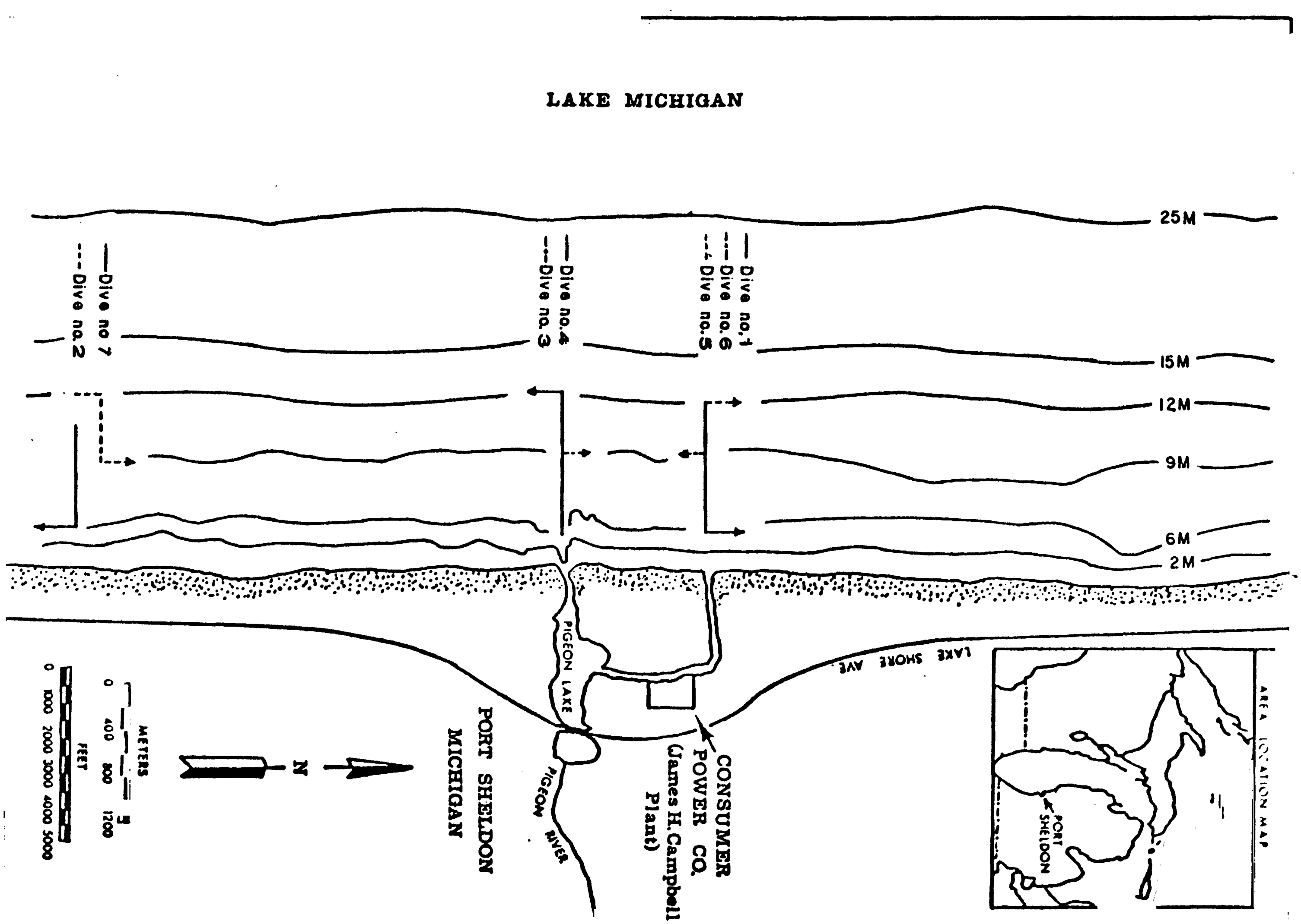


Fig. 5 . Scheme of the J. H. Campbell Plant showing Lake Michigan and the eight diving transects swum to monitor bottom topography, 9-10 August 1977. From Jude et al. (1978).

riprap (crushed limestone 0.1-2.5 m in diameter; 225-900 kg) deposited during intake construction to reduce erosion of in-lake cooling water intake structures.

The standard series dives were conducted using two or three divers equipped with SCUBA. Divers always swam side by side and either 1 or 2 m apart. Divers made observations at the intake station (southeast arm of intake manifold) (Fig. 6) by swimming southwest along the west side of the seven risers and back northeast along the east side of the risers (approximately 50 m total). While swimming, each diver examined a plot of 2 m in width. In addition the divers swam for 5 min, side by side on the sand directly south of the southeast intake arm. Divers were 2 m apart during this swim.

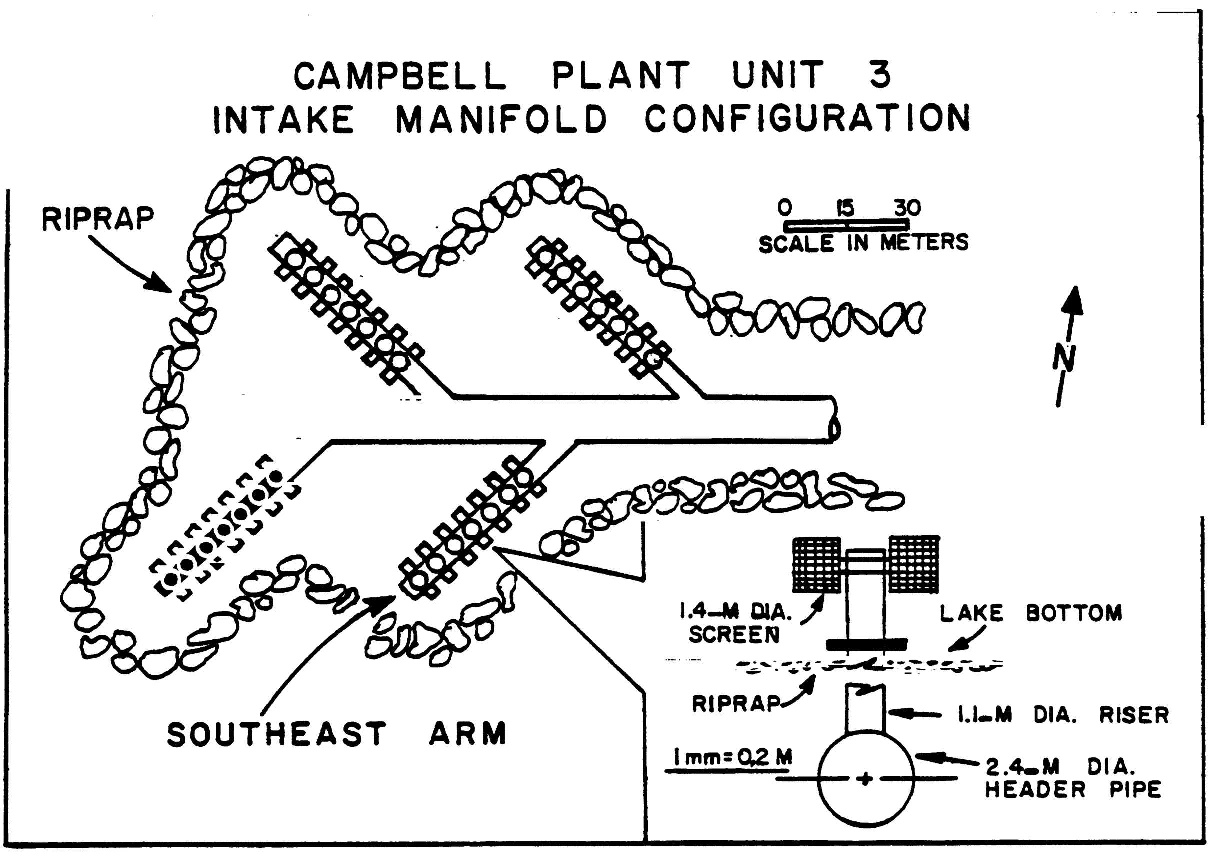


Fig. 6. Scheme of the J. H. Campbell Plant Unit 3 intake manifold depicting site of SCUBA observations during 1979 and 1980. Inset shows enlargement of an individual riser with two accompanying screens.

The previously described stations and observational methods comprise our monthly standard series sampling effort. Due to construction activity in the study area sampling did not begin until June. However, dives were undertaken in May and June to select the best sites for standard series dives.

Observations were made following the format of Dorr and Miller (1975) and were recorded underwater on water-resistant paper. Because of the uneven nature of the riprap substrate at the Campbell Plant, abundance of cryptozoic or demersal organisms was most likely underestimated. Large chunks of limestone (approximately 2 m in diameter) rest on the bottom in such a manner as to produce a vast number of small fissures and interstices which cannot be examined and may contain demersal organisms.

STATISTICS

One objective of this study was to see how fish populations fluctuate from year to year and to detect differences in fish abundances between the reference area and the zone of influence (area of Lake Michigan affected by the intake of cooling water and discharge of heated water). Catch-per-unit-effort (CPE) was utilized as an index of abundance, providing estimates of relative population size. Note that CPE is an index of numerical abundance and not an absolute measure of population size. Replicate samples were taken using trawls, seines and gill nets. Each sample represented one unit of effort. One unit of trawling effort was defined as a 10-min tow, one unit of gill net effort was defined as one lift of one replicate of the net adjusted to a standard 12-h fishing period and one unit of seining effort was defined as a 61-m sweep parallel to shore with the seine. There are many problems equating units of effort of one gear type to effort units of another, so abundance indices for different gear types are not directly comparable (Lawrie and Rahrer 1973). However, CPE values for different gear types may provide complementary information about a particular fish population. For example, individual fish which might avoid trawls might be captured by gill nets. Conversely, fish which are too small to be captured in gill nets are likely to be caught with seines and trawls. Assuming that biases of each gear are constant over time and sampling stations, standardized units of effort for each gear ensured that CPE was a reliable index for abundance for fish populations (Ricker 1975). Although the data were analyzed separately for each gear type for a particular species, the aggregate of the results for all gear types was reviewed for that species.

BMD8V was used to perform the analyses of variance (ANOVA) on the adult and juvenile fish data (Statistical Research Laboratory 1975). Attained significance values for ANOVA F-statistics were generated from TABLES, an interactive computer program for statistical probability distributions (Fox 1978). The Michigan Interactive Data Analysis System (MIDAS - Fox and Guire 1973) was used for analyses of ANOVA residuals. Residuals, defined as the difference between the cell mean and actual data value, were examined to determine how well ANOVA model assumptions were met (Draper and Smith 1966). A FORTRAN program was written to compute the LDTR (Least Detectable True Ratios). MIDAS was used to perform the Wilcoxon signed ranks test on the larvae data.

Design and Analysis Considerations

Statistical analyses were performed on catch data of the six most abundant species of fish collected during field sampling in Lake Michigan. They included: spottail shiner, alewife, rainbow smelt, yellow perch, trout-perch and unidentified Coregoninae. Differences in fish abundance between the reference area and the zone of influence were examined using analysis of variance (ANOVA). These analyses will hopefully provide information to determine what impact the power plant may be having on fish populations. The experimental designs were analyzed as completely crossed, factorial models with YEAR, MONTH, AREA, DEPTH (for some designs) and TIME OF DAY as design variables (Table 5). All factors were considered fixed. The response variable was either number of fish per unit of effort or a transform thereof. We transformed raw data by taking log of the sum of CPE plus one. The addition of one ensured inclusion of zero values of CPE in the transformed data. This transformation was designed to reduce data variance so ANOVA assumptions might be more closely met.

The factorial ANOVA designs were chosen according to species, gear type and presence of zero values in data (Table 5). The YEAR factor was examined for each gear type to see if population abundances were significantly different among the 3 yr. The MONTH factor was expected to explain a considerable amount of variation attributable to seasonal changes in fish abundance. The STATION factor was designed to test for differences between the reference station C (6 m, south) and the zone of influence station L (6 m, north) for trawl and gill net models, while for seining, this factor was designed to test for differences between beach reference station P (1 m, south) and treatment stations Q (south discharge) and R (north discharge). AREA was used in the second trawl design to examine differences between the reference area [stations C (6 m, south) and D (9 m, south)] and the zone of influence [stations L (6 m, north) and N (9 m, north)]. Depth was used in this design to compare abundances between the 6- and 9-m contours. The data for 6- and 9-m stations were analyzed only for 1978-1980 because trawl samples were not collected at station N (9 m, north) in 1977. TIME OF DAY was employed in all of the designs. A main effect or an interaction was considered significant if the attained significance (p) of its statistical test was less than 0.01 ($p < 0.01$); the main effect or interaction was considered highly significant if the attained significance (p) for its test was less than 0.001 ($p < 0.001$).

Assumptions for the ANOVA model were: 1) residuals are normally distributed, 2) variances of the population are constant for all partitions of the population and 3) observations are statistically independent. Balanced factorial ANOVA are robust to the assumptions of normality and homogenous variances. In other words, moderate departures from these assumptions do not completely invalidate results of the model. Violation of the independence assumption may have more serious consequences. Examination of frequency histograms of residuals and plots of residuals versus cell means indicate that the assumptions of normality and homogeneous variances were not seriously violated.

Given that these assumptions are met, sensitivity of the ANOVA model to detect the alternate hypothesis can be calculated. In this study, we were interested in detecting significant differences between areas (or stations). The least detectable true change (LDTC) is the minimum difference in mean abundance between areas (or stations) that can be detected by our experimental design. The formula we used for LDTC, as presented by Jude et al. (1979b), is as follows:

$$\delta = s(2/n)^{\frac{1}{2}} \quad (t_{\alpha,\nu} + t_{2(1-P),\nu})$$

Where: δ = least detectable true change (LDTC)

s = within cell standard deviation of the ANOVA (i.e., the square root of the mean square error)

n = number of observations in each of the two groups being compared

α = significance level

t = Student's t-statistic

ν = degrees of freedom for the error sum of squares of the ANOVA

P = power (the probability that a true difference will be judged significant by the ANOVA test)

Results for all ANOVA models were computed using both raw and log-transformed data. Data for all species and gear types were initially screened by calculating mean catch (which was equal in value to mean CPE since effort for collecting any one sample was always one), its variance and percentage of zero values in the design matrix. Summary statistics for those data sets considered amenable to further statistical analyses (Table 6) showed that percentage of zero catches for these data usually exceeded 25%. Consequently, distribution of values was generally bimodal with modes at zero and near the geometric means. The transformation did, however, yield residuals which were slightly closer to meeting ANOVA assumptions than residuals from raw-data values. Unless stated otherwise, future references to abundance when discussing the ANOVA results will refer to geometric mean abundance derived from log-transformed data. Geometric means for various partitions of the data were derived by back transforming cell means from $\log_{10}$-transformed data. For example, if $\bar{x}$ represents the mean catch for log-transformed data, then $\bar{x}' = 10^{\bar{x}}$ is the geometric mean catch. Use of log-transformed data can yield cell means which are not in the same ranking order as cell means from the original data. If so, the geometric means will also differ in ranking order since the exponential function is monotonic.

When using log-transformed data, the LDTC or δ is expressed as the change in the logarithm of fish numbers and not in terms of the actual numbers of fish. Back transforming δ yields 10^{δ}; 10^{δ} represents the ratio of the mean number of fish per unit effort plus one for reference area RA to that of experimental area PA (plant-influenced area). In the transformed coordinate

Table 5. Experimental designs employed to analyze catch-per-unit-of-effort data for the six most abundant species caught in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1977 through 1980.

Design label (includes gear)	Factor	Levels of factor	Species examined	Comments
TRAWL I	Year Month Station Time of day	1977-1980 June-December reference: C(6 m, south) plant: L(6 m, north) day, night	Spottail shiner Alewife Rainbow smelt Yellow perch Trout-perch Unidentified Coregoninae	For alewife, trout-perch and unidentified Coregoninae data months June through November were analyzed. Yellow perch data months July through September were analyzed.
TRAWL II	Year Month Area Depth Time of day	1978-1980 May-December reference: C(6 m, south), D(9 m, south) plant: L(6 m, north), N(9 m, north) 6 m, 9 m day, night	Spottail shiner Alewife Rainbow smelt Yellow perch Trout-perch Unidentified Coregoninae	For alewife and unidentified Coregoninae data months June through November were analyzed. For trout-perch data months May through November were analyzed and for yellow perch months July through September were included in experimental design.

Table 5. Continued.

Design label (includes gear)	Factor	Levels of factor	Species examined	Comments
BOTTOM GILL NET I	Year	1977-1980	Spottail shiner	Bottom gill net catch data for rainbow smelt, trout-perch and unidentified Coregoninae were not analyzed (using ANOVA) because catches were too low. Alewife and yellow perch data were analyzed for July through September only.
	Month	July, August, September and November	Alewife	
	Station	reference: C(6 m, south) plant: L(6 m, north)	Yellow perch	
	Time of day	day, night		
BOTTOM GILL NET II	Year	1978-1980	Spottail shiner	Catch data for alewife were analyzed for June through September and for yellow perch only months August and September were included in experimental design.
	Month	May-October	Alewife	
	Station	reference: C(6 m, south) plant: L(6 m, north)	Yellow perch	
	Time of day	day, night		
BOTTOM GILL NET III	Month	May-October (1980 only)	Spottail shiner	Only 1980 catch data were analyzed. Alewife data for months June through September were analyzed. For yellow perch only months August and September were included in experimental design.
	Area	reference: C(6 m, south), D(9 m, south) plant: L(6 m, north), N(9 m, north)	Alewife	
			Yellow perch	
	Depth	6 m, 9 m		
	Time of day	day, night		

Table 5. Continued.

Design label (includes gear)	Factor	Levels of factor	Species examined	Comments
SURFACE GILL NET I	Year	1977-1980	Alewife	Only alewife data were analyzed; catches of other species were too low.
	Month	July-September		
	Station	reference: C(6 m, south) plant: L(6 m, north)		
	Time of day	day, night		
SURFACE GILL NET II	Year	1978-1980	Alewife	Only alewife data were analyzed; catches of other species were too low.
	Month	May- September		
	Station	reference: C(6 m, south) plant: L(6 m, north)		
	Time of day	day, night		
SEINE	Year	1977-1980	Spottail shiner Alewife	Only spottail shiner and alewife data were analyzed, catches of other species were too low. Months June through September were included in the alewife experimental design.
	Month	June-November		
	Station	reference: P(south) plant: Q(south discharge) R(north discharge)		
	Time of day	day, night		

Table 6. Descriptive statistics for catch-per-unit-of-effort (CPE) data used in the experimental designs for the six most abundant species caught in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan for years 1977 through 1980. N is number of observations included in the experimental design; $\bar{X}$ is the mean number of fish caught per one unit of effort for the data set.

Design	N	Maximum catch (no. fish)	$\bar{X}$	Standard deviation	Percentage of zero catch data
TRAWL I					
Spottail shiner	224	736	23.0	69.2	42.0
Alewife	192	4287	100.4	407.8	23.4
Rainbow smelt	224	2268	118.8	286.5	8.9
Yellow perch	96	90	6.0	12.9	40.6
Trout-perch	192	144	9.9	19.4	47.9
Unidentified Coregoninae	192	395	26.2	65.1	35.9
TRAWL II					
Spottail shiner	384	736	27.4	76.6	35.2
Alewife	288	4287	122.9	434.5	29.5
Rainbow smelt	384	2268	146.0	295.7	7.0
Yellow perch	144	195	6.5	19.5	43.8
Trout-perch	336	144	11.8	20.2	37.2
Unidentified Coregoninae	288	503	36.9	70.1	20.8
BOTTOM GILL NET I					
Spottail shiner	128	244	18.6	42.0	39.8
Alewife	96	195	16.8	37.6	27.1
Yellow perch	96	34	6.9	7.9	21.9
BOTTOM GILL NET II					
Spottail shiner	144	244	24.2	43.8	33.3
Alewife	120	185	17.1	36.4	25.0
Yellow perch	48	34	8.2	7.9	14.6
BOTTOM GILL NET III					
Spottail shiner	96	244	19.8	43.5	27.1
Alewife	64	168	15.8	34.4	35.9
Yellow perch	48	34	6.9	9.1	20.8
SURFACE GILL NET I					
Alewife	64	213	29.3	41.5	31.2

Table 6 continued.

Design	N	Maximum catch (no. fish)	$\bar{X}$	Standard deviation	Percentage of zero catch data
SURFACE GILL NET II					
Alewife	120	213	22.7	36.8	38.3
SEINE					
Spottail shiner	240	1678	68.7	204.4	22.5
Alewife	190	6174	225.0	697.4	27.1

system (i.e., log-transformed system) changes will be detectable if $|\bar{x}_{RA} - \bar{x}_{PA}| > \delta$ where $\bar{x}_{RA}$ and $\bar{x}_{PA}$ refer to the log-transformed mean catches at areas RA and PA respectively. In the original coordinate system, differences are detectable whenever:

$$\frac{\bar{x}'_{RA}}{\bar{x}'_{PA}} < 10^{-\delta} \quad \text{or} \quad \frac{\bar{x}'_{RA}}{\bar{x}'_{PA}} > 10^{\delta}$$

We shall refer to the quantity 10^{δ} as the least detectable true ratio (LDTR).

Power Analysis

The LDTRs (Least Detectable True Ratios) are ratios involving geometric mean number of fish. Least detectable true ratios for the designs employed ranged from 1.24 to 2.97 with most occurring between 1.3 and 1.7 (for $\alpha = 0.01$ and Power = 0.95) (Table 7). The lowest LDTR (for $\alpha = 0.01$ and Power = 0.95), 1.24, was for the second trawl design for trout-perch; thus for this design the mean abundance at one area should have to be at least 24% greater than the mean abundance at the other area to detect a difference in abundance between areas. Overall the LDTRs of ANOVAs including just 1977 through 1979 data were lower than those for ANOVAS including 1977 through 1980 data. This was probably due to increased variance in the data caused by difference in catch distribution between 1980 and previous years. LDTRs were highest for surface gill net and seine designs. Among species, sensitivity of the ANOVA to detect a significant difference between areas was lowest for alewife, which may be related to alewife migration and highly variable recruitment of their young. The trawl was probably the best gear for assessing impacts of plant operation; in general, LDTRs were lower for trawl designs than for designs for other gear. For all the trawl designs except the first trawl design for alewife, the LDTRs were less than or equal to 1.61. Given that the assumptions of the power analysis have been met for these trawl designs (same assumptions as for ANOVA), a 61% greater abundance at one station than at the other should be

Table 7. Least detectable true ratio (LDTR) for each experimental design employed for spottail shiners, alewives, rainbow smelt, yellow perch, trout-perch and unidentified Coregoninae caught in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1977 through 1980. Alpha (α) is the size of the type I error; it is the probability of rejecting the null hypothesis given that it is true; power is the probability of rejecting the null hypothesis given it is false. See Table 5 for design descriptions.

DESIGN	α	SPOTTAIL SHINER Power .90	SPOTTAIL SHINER Power .95	ALEWIFE Power .90	ALEWIFE Power .95	RAINBOW SMELT Power .90	RAINBOW SMELT Power .95	YELLOW PERCH Power .90	YELLOW PERCH Power .95	TROUT-PERCH Power .90	TROUT-PERCH Power .95	UNIDENTIFIED COREGONINAE Power .90	UNIDENTIFIED COREGONINAE Power .95
TRAWL I	.01	1.34	1.37	1.71	1.80	1.54	1.61	1.42	1.47	1.25	1.28	1.47	1.52
	.02	1.31	1.35	1.65	1.74	1.50	1.56	1.39	1.44	1.24	1.26	1.43	1.48
	.05	1.28	1.31	1.57	1.65	1.44	1.50	1.34	1.39	1.21	1.23	1.38	1.43
	.10	1.25	1.28	1.50	1.58	1.39	1.45	1.30	1.35	1.19	1.21	1.33	1.38
TRAWL II	.01	1.29	1.32	1.51	1.57	1.40	1.44	1.35	1.38	1.22	1.24	1.49	1.55
	.02	1.27	1.30	1.47	1.53	1.37	1.41	1.32	1.36	1.20	1.23	1.45	1.51
	.05	1.24	1.27	1.41	1.47	1.32	1.37	1.28	1.32	1.18	1.20	1.40	1.45
	.10	1.21	1.24	1.37	1.42	1.29	1.33	1.25	1.29	1.16	1.18	1.35	1.40
BOTTOM GILL NET I	.01	1.44	1.49	1.78	1.88			1.56	1.63				
	.02	1.40	1.45	1.71	1.81			1.51	1.58				
	.05	1.36	1.40	1.62	1.71			1.45	1.51				
	.10	1.31	1.36	1.54	1.63			1.40	1.46				
BOTTOM GILL NET II	.01	1.43	1.48	1.64	1.72			2.14	2.30				
	.02	1.39	1.44	1.59	1.66			2.02	2.18				
	.05	1.35	1.39	1.51	1.58			1.87	2.01				
	.10	1.31	1.35	1.45	1.52			1.75	1.88				
BOTTOM GILL NET III	.01	1.56	1.63	1.89	2.01			2.01	2.15				
	.02	1.52	1.58	1.81	1.92			1.91	2.04				
	.05	1.45	1.51	1.69	1.80			1.78	1.90				
	.10	1.40	1.46	1.60	1.70			1.67	1.79				
SURFACE GILL NET I	.01			2.70	2.97								
	.02			2.51	2.76								
	.05			2.27	2.50								
	.10			2.09	2.30								
SURFACE GILL NET II	.01			1.75	1.84								
	.02			1.68	1.77								
	.05			1.59	1.68								
	.10			1.52	1.60								
SEINE	.01	1.88	1.99	2.15	2.31								
	.02	1.80	1.91	2.04	2.19								
	.05	1.69	1.80	1.90	2.04								
	.10	1.61	1.71	1.78	1.91								

detected. The higher LDTRs for alewife are not a reflection of the experimental design, but rather an indication of the naturally high variations in abundance of alewives within the inshore zone.

Fish Larvae Analysis

The Wilcoxon signed ranks test was performed on fish larvae and fish egg data to investigate differences in larvae and fish egg densities between the reference (south) transect and the plant-influenced or discharge (north) transect. This statistical technique is the nonparametric analogue of the t-test for paired observations (Conover 1971). With a few exceptions, for each tow performed at a particular depth contour and a particular stratum in the water column at one transect there was a corresponding tow performed at the same depth contour and stratum at the other transect for each sampling period. Thus, during a particular diel period of larvae sampling, pairs of densities could be calculated for all taxons of larvae found and this technique could be used. To apply this procedure, both beach tow replicate samples were averaged to yield one value for the 0.5-m depth in the beach zone. The four beach tows [two at both stations Q (south of discharge) and R (north of discharge)] were averaged to yield one value to be paired with the average value of the beach tows at the south transect. The two beach sled tows at the north transect (one at both stations Q and R) were averaged to pair with the beach sled tow at the south transect. Any incomplete (one missing observation) pair of observations negated calculation of the test statistic. All zero differences or ties between pairs of observations were ignored. For most of the 1977 sampling year complete pairs of observations were available from the beach to 12 m; the 15-m depth contour was sampled for the south transect but not for the north one.

The Wilcoxon signed ranks test was applied to data for each year separately from 1977 to 1980 for each of the more abundant taxons of larvae collected as well as fish eggs. The test was also conducted for all 4 yr of data pooled for each of those taxons. A difference in densities between transects was considered significant if the attained significance level for the statistic was less than 0.05.

RESULTS AND DISCUSSION

TOTAL CATCH

The total catch of various species of fish in the vicinity of the Campbell Plant is a relative index of abundance of fish populations in Lake Michigan. When fish are collected consistently with the same gear, frequency and effort, comparisons can be made among various areas and years. However, a number of factors can affect total catch and should be considered when discussing these data. Strong year classes and, conversely, weak ones have dramatic effects on total catch as YOY always comprise the highest proportion of our catches. Consequently their fluctuations usually explain most of the variability seen in total catches. Timing, frequency and duration of upwellings (for example see Fig. 7) can also change the catch composition in a given month by causing the usual warm-water species to be replaced by cold-water species, such as lake trout, smelt and bloaters. Comparisons of catches among years are thus drastically affected. Another cause of catch variation is timing of gear deployment. Depending upon what time of the month our gear are used we may or may not encounter migrations, spawning aggregations, or as discussed, upwellings. Lastly, there have been some minor changes in stations fished over the 1977-1980 study period, but these were minor deletions and additions which are not expected to affect total catch trends.

During 1977-1980, we collected 48 different species of juvenile and adult fish in Lake Michigan near the J. H. Campbell Plant (Table 8). The list of larval fish collected (Table 9) does not include any new species, but the collection of lake trout larvae for the first time in southern Lake Michigan since planted lake trout were introduced in the 1960s, is a notable entry (for details see Jude et al. 1981b and RESULTS AND DISCUSSION--Lake Trout). Among these fish were 17 families, ranging from the ancient and threatened lake sturgeon to the recently stocked array of salmonids, e.g., coho salmon, chinook salmon, brown trout and rainbow trout.

In the study area, the family with the most members was Salmonidae with nine entries, followed by the Cyprinidae with eight and the Catostomidae with six. Among fish caught are a number of marine species, including the ubiquitous alewife, rainbow smelt and the recently introduced salmon. Overall, the historical species complex in Lake Michigan has changed drastically over recent history (see Smith 1968; Christie 1974). The more abundant and long-standing species in Lake Michigan, such as the lake herring, members of the chub complex, lake trout, burbot and lake whitefish have been overfished, preyed upon by sea lamprey, and have suffered destruction of spawning habitat and nursery areas which have resulted in wholesale extinction of some species and severe reductions in the abundance of others. Concurrent with this upheaval in species interactions was the introduction of exotic species like alewives and smelt, which are numerical dominants in our present catches and undoubtedly in Lake Michigan in general. Certain species like deepwater sculpins, which are abundant in the deeper regions of the lake, were probably less affected by these changes than other endemic species. It is against this backdrop of species interactions, fish stocking programs and the continual eutrophication of Lake Michigan that we must evaluate the impact of

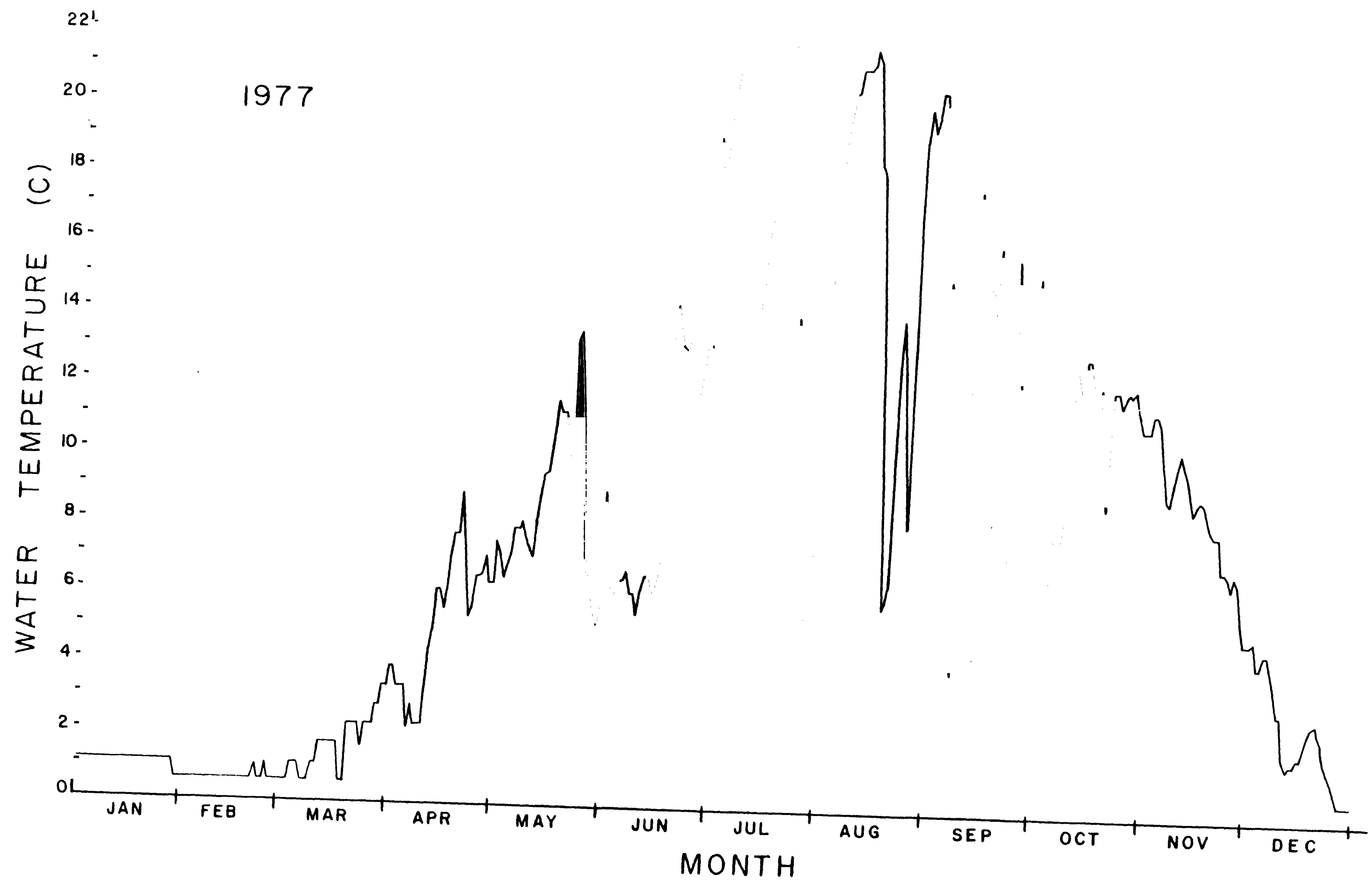


Fig. 7. Daily Lake Michigan water temperatures during 1977-1980. Measurements are from raw Lake Michigan water taken in by the Grand Rapids Filtration Plant located at West Olive, Michigan. Intake depth was 12 m.

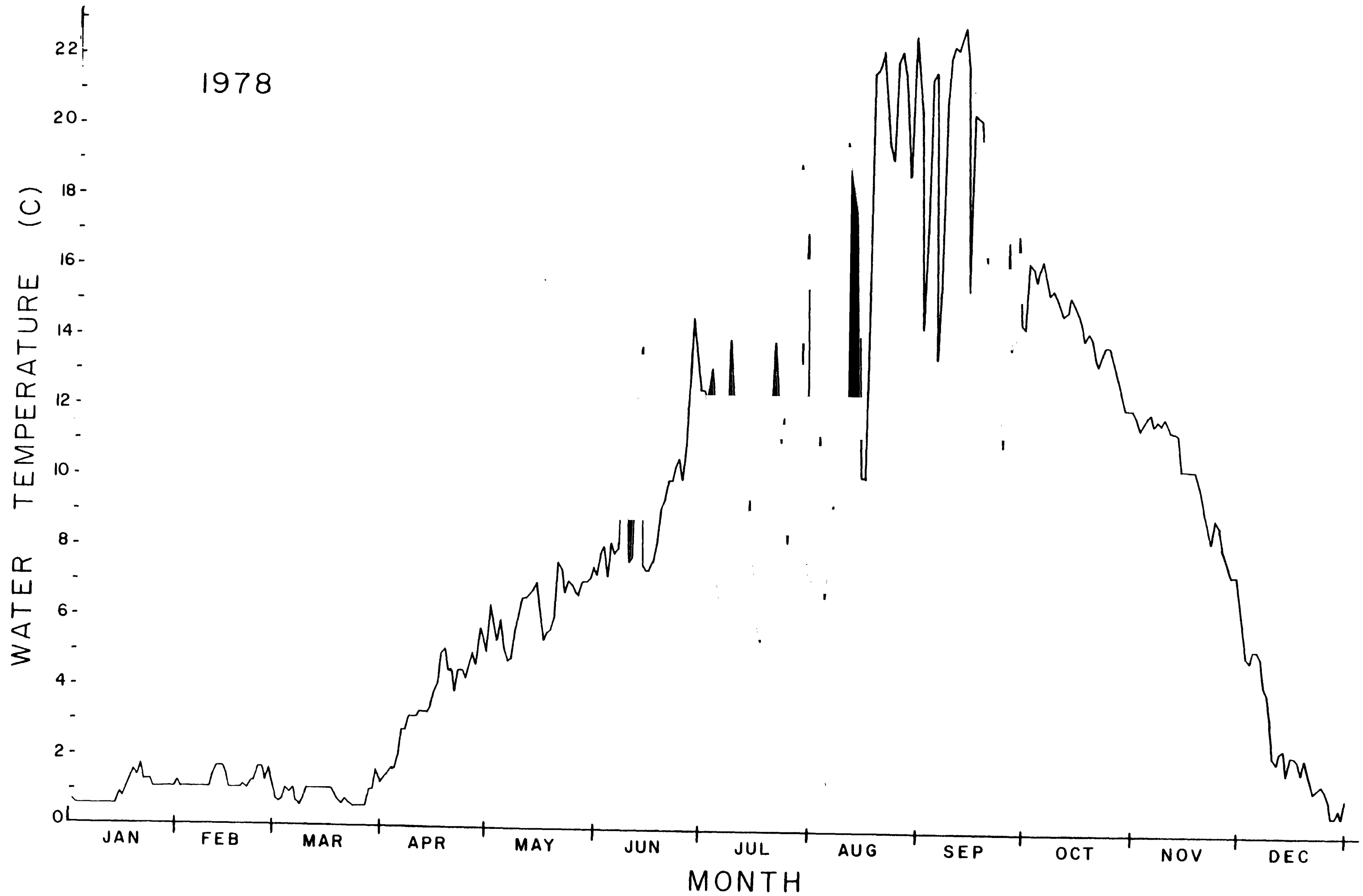


Fig. 7. Continued.

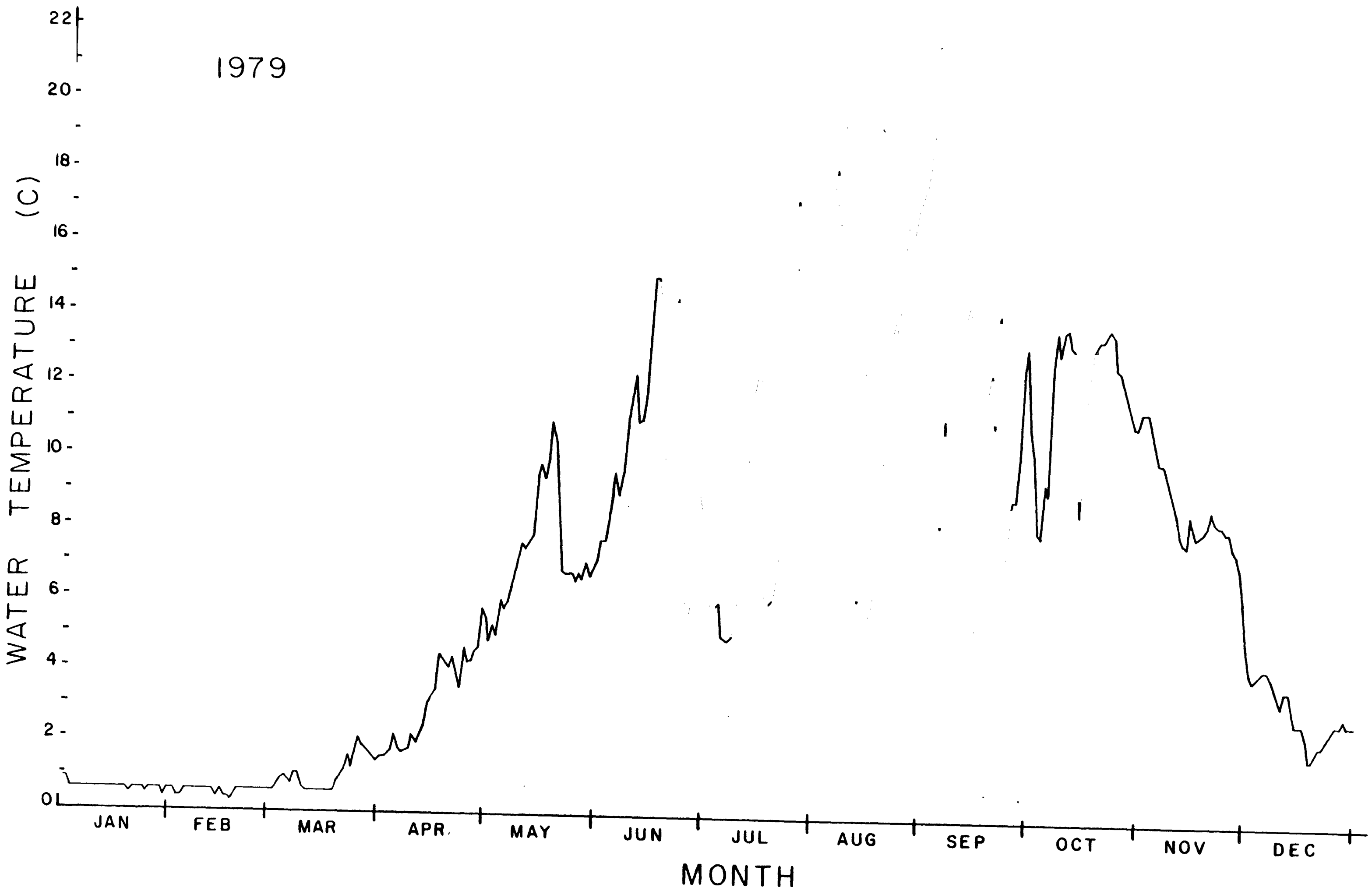


Fig. 7. Continued.

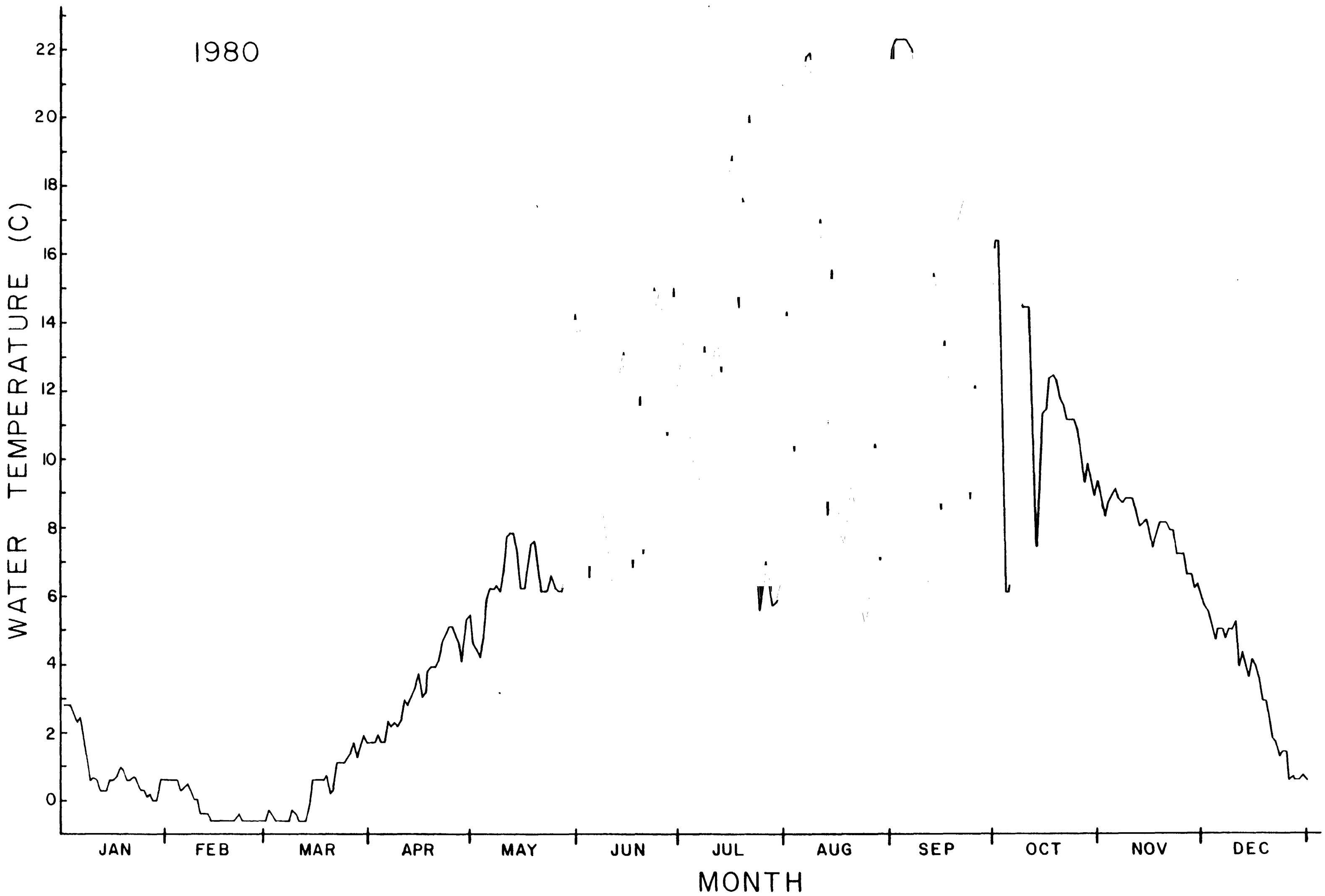


Fig. 7. Continued.

Table 8. Family name, scientific name, common name and codes for all species of juvenile and adult fish captured (from 1977 through 1980) in Lake Michigan near the J. H. Campbell Plant. An X denotes presence in a given year. Names assigned according to Robins et al. (1980).

Family, Scientific and Common Name	Code	1977	1978	1979	1980
Acipenseridae					
Acipenser fulvescens Rafinesque Lake sturgeon	LG	X		X	
Atherinidae					
Labidesthes sicculus (Cope) Brook silverside	SV	X			
Catostomidae					
Carpiodes cyprinus (Lesueur) Quillback	QL		X		X
Catostomus catostomus (Forster) Longnose sucker	LS	X	X	X	X
Catostomus commersoni (Lacèpéde) White sucker	WS	X	X	X	X
Moxostoma anisurum (Rafinesque) Silver redhorse	MA	X	X	X	X
Moxostoma erythrurum (Rafinesque) Golden redhorse	GR		X	X	X
Moxostoma macrolepidotum (Lesueur) Shorthead redhorse	SR	X	X	X	X
Centrarchidae					
Lepomis cyanellus Rafinesque Green sunfish	GN			X	
Lepomis gibbosus (Linnaeus) Pumpkinseed	PS	X			
Lepomis macrochirus Rafinesque Bluegill	BG	X	X		X
Micropterus dolomieui Lacèpéde Smallmouth bass	SB		X		
Pomoxis nigromaculatus (Lesueur) Black crappie	BC				X
Clupeidae					
Alosa pseudoharengus (Wilson) Alewife	AL	X	X	X	X
Dorosoma cepedianum (Lesueur) Gizzard shad	GS	X	X	X	X

Table 8 continued.

Family, Scientific and Common Name	Code	1977	1978	1979	1980
Cottidae					
Cottus bairdi Girard Mottled sculpin	MS	X		X	X
Cottus cognatus Richardson Slimy sculpin	SS	X	X	X	X
Myoxocephalus thompsoni (Girard) Deepwater sculpin	FS				X
Cyprinidae					
Carassius auratus (Linnaeus) Goldfish	GF		X		
Cyprinus carpio Linnaeus Common carp	CP	X	X	X	X
Notemigonus crysoleucas (Mitchill) Golden shiner	GL				X
Notropis atherinoides Rafinesque Emerald shiner	ES	X	X	X	X
Notropis hudsonius (Clinton) Spottail shiner	SP	X	X	X	X
Pimephales notatus (Rafinesque) Bluntnose minnow	BM		X	X	
Pimephales promelas Rafinesque Fathead minnow	PP		X		
Rhinichthys cataractae (Valenciennes) Longnose dace	LD	X			X
Esocidae					
Esox lucius Linnaeus Northern pike	NP		X		X
Gadidae					
Lota lota (Linnaeus) Burbot	BR	X	X		X
Gasterosteidae					
Pungitius pungitius (Linnaeus) Ninespine stickleback	NS	X	X	X	X
Ictaluridae					
Ictalurus natalis (Lesueur) Yellow bullhead	YB				X
Ictalurus punctatus (Rafinesque) Channel catfish	CC	X	X	X	X

Table 8 continued.

Family, Scientific and Common Name	Code	1977	1978	1979	1980
Osmeridae					
Osmerus mordax (Mitchill)	SM	X	X	X	X
Rainbow smelt					
Percidae	JD	X	X	X	X
Etheostoma nigrum Rafinesque					
Johnny darter					
Perca flavescens (Mitchill)	YP	X	X	X	X
Yellow perch					
Stizostedion vitreum vitreum (Mitchill)	WL		X		X
Walleye					
Percopsidae					
Percopsis omiscomaycus (Walbaum)	TP	X	X	X	X
Trout-perch					
Salmonidae					
Coregonus artedii Lesueur	LH				X
Lake herring or cisco					
Coregonus clupeaformis (Mitchill)	LW	X	X	X	X
Lake whitefish					
Coregonus hoyi	BL	X	X	X	X
Bloater					
Coregonus spp.	XC	X	X	X	X
Unidentified Coregoninae					
Oncorhynchus kisutch (Walbaum)	CM	X	X	X	X
Coho salmon					
Oncorhynchus tshawytscha (Walbaum)	CH	X	X	X	X
Chinook salmon					
Prosopium cylindraceum (Pallas)	RW	X	X	X	X
Round whitefish					
Salmo gairdneri Richardson	RT	X	X	X	X
Rainbow trout					
Salmo trutta Linnaeus	BT	X	X	X	X
Brown trout					
Salvelinus namaycush (Walbaum)	LT	X	X	X	X
Lake trout					
Sciaenidae					
Aplodinotus grunniens Rafinesque	FD		X		X
Freshwater drum					
Umbridae					
Umbra limi (Kirtland)	MM				X
Central mudminnow					

Table 9. Taxons and abbreviations for all groups of fish larvae captured from 1977 through 1980 in Lake Michigan near the J. H. Campbell Plant. An L denotes presence of fish larvae and an F represents fry. Names assigned according to Robins et al. (1980).

Scientific and Common Name	Code	1977	1978	1979	1980
Catostomidae					
Catostomidae spp.	XS			L	
Unidentified Catostomidae					
Carpiodes cyprinus (Lesueur)	QL		L‡		
Quillback					
Centrarchidae					
Lepomis gibbosus (Linnaeus)	PS	F			
Pumpkinseed					
Lepomis macrochirus Rafinesque	BG	F			
Bluegill					
Lepomis spp.	XL	L		L	L
Unidentified *Lepomis*					
Pomoxis spp.	PM	L		L	L
Unidentified *Pomoxis*					
Clupeidae					
Alosa pseudoharengus (Wilson)	AL	L,F	L,F	L,F	L,F
Alewife					
Dorosoma cepedianum (Lesueur)	GS			L	L
Gizzard shad					
Cottidae					
Cottus cognatus Richardson	SS	L	F	L,F	L
Slimy sculpin					
Myoxocephalus thompsoni (Girard)	FS	L	L	L	L
Deepwater sculpin					
Cottidae spp.	UC		L		
Unidentified Cottidae					
Cyprinidae					
Cyprinus carpio Linnaeus	CP	L	L	L	L
Common carp					
Notropis atherinoides Rafinesque	ES		L	L	L
Emerald shiner					
Notropis hudsonius (Clinton)	SP	L,F	L,F	L,F	L,F
Spottail shiner					
Pimephales promelas Rafinesque	PP			F	
Fathead minnow					
Cyprinidae spp.	XM	L,F	L	L	
Unidentified Cyprinidae					

Table 9 continued.

Scientific and Common Name	Code	1977	1978	1979	1980
Gadidae					
Lota lota (Linnaeus) Burbot	BR		L	L	L
Gasterosteidae					
Pungitius pungitius (Linnaeus) Ninespine stickleback	NS		L,F	L	L,F
Gasterosteidae spp. Unidentified stickleback	XG	L			
Osmeridae					
Osmerus mordax (Mitchill) Rainbow smelt	SM	L,F	L,F	L,F	L,F
Percidae					
Etheostoma nigrum Rafinesque Johnny darter	JD	F	L,F	L,F	L,F
Perca flavescens (Mitchill) Yellow perch	YP	L	L,F	L,F	L,F
Percina caprodes (Rafinesque) Logperch	LP		L		
Percopsidae					
Percopsis omiscomaycus (Walbaum) Trout-perch	TP	L	L	L,F	L,F
Salmonidae					
Coregoninae spp. Unidentified Coregoninae	XC		L	L,F	L,F
Oncorhynchus tshawytscha (Walbaum) Chinook salmon	CH			F	
Salvelinus namaycush (Walbaum) Lake trout	LT				L,F
Larvae damaged beyond recognition	XP	L	L	L	L
Unidentified Pisces	XX	L	L		

†Appeared as white sucker in Jude et al. 1979a.

the Campbell Plant. Any conclusions we make must take into consideration the vastness of the Lake Michigan ecosystem, the present species complex in the lake and the specific life histories of each fish and how that information relates to the present intake and discharge system at the plant.

Examining the total yearly catch of all fish caught by all gear in Lake Michigan over the 1977-1980 preoperational period, showed an unexpected shift in species dominance from alewife in 1977-1978 to rainbow smelt in 1979-1980 (Table 10). Alewives were 69% and 49% respectively of the total fish caught in the first 2 yr, while they declined to 36%, then 19% in the latter 2 yr. Though this implies a catastrophic decline in alewife abundance over the 4-yr period, careful analysis (see RESULTS AND DISCUSSION, <u>Alewife</u>) showed that most variation was due to dramatic declines in alewife YOY numbers in the catch. The adult component of the catch remained relatively stable over the 4 yr. Pelagic planktivorous fish, like alewives, exhibit extreme fluctuations in abundance and our findings are certainly not unexpected. In fact, alewife populations in recent years may have finally reached a certain level of stability since the 1960s when millions of dead fish littered Lake Michigan beaches. Increased salmonid predation and commercial fishing may be mortality vectors tending to keep populations in check. Our recent data (see RESULTS AND DISCUSSION, <u>Unidentified Coregoninae</u>) show that bloaters, believed to be suppressed by commercial fishing and alewife abundance, are now increasing in numbers in Lake Michigan.

Rainbow smelt comprised 16, 28, 38 and 44% of the numbers of fish collected during 1977 to 1980, respectively. Again, a strong year class was produced in the latter 2 yr of our 4-yr study, causing these fish to be the most abundant fish collected during 1979-1980. Most of the catch was comprised of YOY and yearlings trawled during late summer and fall.

Spottail shiner catch appeared to be stable over the 4 yr, ranging from 7883 fish (10% of catch) in 1977, a year of incomplete fishing, to 15,273 fish in 1980 (18%). June through September were months of maximum catch of spottails. Spottails apparently are not as drastically affected by fluctuations of other dominant species such as the alewife and smelt. Spottails are usually separated temporally from smelt and spatially from alewife. They are demersal species, feeding on benthos and epibenthic zooplankton, organisms that are not the main food supply of alewives, which feed in mid-water. Spottails are also nearshore, beach-zone fishes, which keeps them spatially separated from rainbow smelt adults. Adult smelt inhabit cooler water offshore, while YOY and yearlings are usually in deeper water (6-12 m) than spottails.

Yellow perch, an important sport fish in the vicinity of the plant, was a consistent part of our total catch, varying between 1 and 2% of the total number of fish caught. Large year classes of perch apparently were produced in 1977 (1254 fish) and 1980 (1715 fish), resulting in high total catches during these years because of the large YOY component in the catches. In 1978 and 1979, lower catches (1078 and 605 fish respectively) were observed. Yellow perch were very responsive to water temperature, as was obvious from the 1979 catch of 605 fish during a year of frequent upwellings and cold inshore temperatures (see RESULTS AND DISCUSSION, <u>Yellow Perch</u> for more detail). Yellow perch were caught in highest numbers during August and September, when YOY are recruited to fishing gear and yearlings are sometimes

Table 10. Summary of all fish species caught by all gear types during June to December 1977 and April to December 1978-1980 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan.

1977

SPECIES	MONTHS JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	% OF TOTAL
ALEWIFE	2198	5850	13680	16314	9413	6409	0	53864	68.522
RAINBOW SMELT	1065	554	7418	2706	353	70	732	12898	16.408
SPOTTAIL SHINER	559	1207	1444	4021	366	88	198	7883	10.028
YELLOW PERCH	92	147	448	463	7	43	54	1254	1.595
TROUT-PERCH	326	221	129	133	36	43	5	893	1.136
UNIDENTIFIED COREGONINAE	73	46	4	38	234	61	4	460	0.586
JOHNNY DARTER	116	13	17	73	68	10	1	298	0.379
WHITE SUCKER	3	51	151	84	0	4	1	294	0.374
LAKE TROUT	4	56	1	120	1	18	1	201	0.256
GIZZARD SHAD	0	3	14	50	13	94	0	174	0.221
NINESPINE STICKLEBACK	87	16	11	14	3	2	0	133	0.169
COHO SALMON	47	0	0	3	0	4	0	54	0.069
BROWN TROUT	11	6	3	15	0	14	0	49	0.062
SLIMY SCULPIN	12	5	0	0	3	1	23	44	0.056
LONGNOSE SUCKER	0	16	13	6	0	1	0	36	0.046
SILVER REDHORSE	0	6	2	3	0	1	0	12	0.015
LAKE WHITEFISH	8	2	0	1	0	0	0	11	0.013
RAINBOW TROUT	0	0	0	1	3	4	0	8	0.010
ROUND WHITEFISH	0	1	0	3	1	2	1	8	0.010
COMMON CARP	0	4	2	1	0	0	0	7	0.009
CHANNEL CATFISH	0	0	6	0	0	0	0	6	0.008
CHINOOK SALMON	1	0	0	1	0	2	0	4	0.005
BLUEGILL	0	0	0	0	4	0	0	4	0.005
MOTTLED SCULPIN	4	0	0	0	0	0	0	4	0.005
LONGNOSE DACE	0	0	0	0	1	2	0	3	0.004
BROOK SILVERSIDE	0	0	0	0	1	0	0	1	0.001
SHORTHEAD REDHORSE	0	0	1	0	0	0	0	1	0.001
EMERALD SHINER	0	0	1	0	0	0	0	1	0.001
LAKE STURGEON	0	1	0	0	0	0	0	1	0.001
PUMPKINSEED	0	0	0	0	1	0	0	1	0.001
BURBOT	0	0	0	0	0	0	1	1	0.001
TOTALS	4606	8205	23345	24050	10508	6873	1021	78608	

1978

SPECIES	MONTHS APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	% OF TOTAL
ALEWIFE	21	880	566	3554	1583	1856	9305	26846	6	44617	49.038
RAINBOW SMELT	1093	4046	2492	6652	6216	2279	1116	1083	351	25328	27.838
SPOTTAIL SHINER	26	425	3083	4222	3471	1045	245	142	105	12764	14.029
UNIDENTIFIED COREGONINAE	0	5	191	540	203	19	1666	479	18	3121	3.430
TROUT-PERCH	11	320	452	357	400	204	22	56	19	1841	2.023
YELLOW PERCH	8	3	8	142	302	539	28	19	29	1078	1.185
NINESPINE STICKLEBACK	5	33	143	151	80	0	2	0	0	414	0.455
JOHNNY DARTER	0	29	48	36	89	56	62	36	6	362	0.398
WHITE SUCKER	0	39	29	78	78	79	5	11	0	319	0.351
SLIMY SCULPIN	61	129	13	32	9	0	0	1	34	279	0.307
LAKE TROUT	31	32	22	15	7	2	96	53	0	258	0.284
GIZZARD SHAD	0	0	0	1	65	58	15	18	32	189	0.208
BROWN TROUT	41	23	20	11	4	5	3	7	0	114	0.125
LONGNOSE SUCKER	1	31	9	16	2	9	2	3	0	73	0.080
COHO SALMON	2	7	18	16	2	7	3	1	0	56	0.062
EMERALD SHINER	0	0	3	0	16	27	0	4	0	50	0.055
CHINOOK SALMON	4	1	13	7	0	3	0	1	0	29	0.032
BLUNTNOSE MINNOW	0	0	0	0	1	13	0	1	0	15	0.016
COMMON CARP	2	1	0	0	7	2	1	0	0	13	0.014
ROUND WHITEFISH	1	1	2	0	3	0	1	1	1	10	0.011
RAINBOW TROUT	2	2	0	0	0	0	1	4	0	9	0.010
LAKE WHITEFISH	4	1	2	1	1	0	0	0	0	9	0.010
WALLEYE	0	0	0	0	6	0	0	0	1	7	0.008
SILVER REDHORSE	0	0	0	0	0	4	0	0	0	4	0.004
QUILLBACK	0	0	1	0	2	1	0	0	0	4	0.004
BURBOT	0	0	0	0	1	0	2	1	0	4	0.004
GOLDEN REDHORSE	0	0	0	1	0	3	0	0	0	4	0.004
CHANNEL CATFISH	0	0	0	0	1	2	0	0	0	3	0.003
BLUEGILL	0	0	0	0	0	1	1	0	0	2	0.002
NORTHERN PIKE	0	0	0	0	1	0	1	0	0	2	0.002
SMALLMOUTH BASS	0	0	0	0	1	1	0	0	0	2	0.002
SHORTHEAD REDHORSE	0	0	1	0	0	0	0	0	0	1	0.001
FATHEAD MINNOW	0	0	0	0	1	0	0	0	0	1	0.001
FRESHWATER DRUM	0	0	0	0	0	1	0	0	0	1	0.001
GOLDFISH	0	0	0	1	0	0	0	0	0	1	0.001
TOTALS	1313	6008	7116	15833	12552	6216	12577	28767	602	90984	

Table 10. Continued.

1979

SPECIES	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	% OF TOTAL
	MONTHS										
RAINBOW SMELT	305	3367	211	2108	17306	4275	599	1037	820	30028	38.400
ALEWIFE	0	449	1199	677	2703	1193	4259	17846	164	28490	36.434
SPOTTAIL SHINER	31	1313	3442	1748	1315	417	783	219	206	9474	12.116
UNIDENTIFIED COREGONINAE	0	8	309	2730	405	429	392	1431	9	5713	7.306
TROUT-PERCH	4	440	137	514	274	171	136	72	7	1755	2.244
YELLOW PERCH	12	13	36	103	103	87	11	40	200	605	0.774
WHITE SUCKER	0	47	42	113	42	158	7	4	0	413	0.528
JOHNNY DARTER	7	99	78	37	33	68	50	17	16	405	0.518
NINESPINE STICKLEBACK	2	55	143	167	1	0	1	3	1	373	0.477
LAKE TROUT	9	13	13	22	13	27	87	37	1	222	0.284
LONGNOSE SUCKER	0	48	14	97	4	30	12	3	0	208	0.266
SLIMY SCULPIN	61	65	2	1	1	0	1	1	24	156	0.199
BROWN TROUT	27	16	13	9	4	12	5	2	0	88	0.113
CHINOOK SALMON	4	21	16	11	2	10	1	2	0	67	0.086
ROUND WHITEFISH	2	4	4	0	2	6	19	6	1	44	0.056
GIZZARD SHAD	3	1	1	1	2	2	21	2	2	35	0.045
RAINBOW TROUT	17	1	0	0	0	0	5	6	0	29	0.037
LAKE WHITEFISH	0	0	9	12	1	5	0	0	0	27	0.035
COHO SALMON	4	4	0	0	3	4	3	0	0	18	0.023
COMMON CARP	2	0	1	0	2	1	2	2	0	10	0.013
GOLDEN REDHORSE	0	0	2	7	0	0	1	0	0	10	0.013
EMERALD SHINER	3	2	0	0	2	0	0	0	0	7	0.009
CHANNEL CATFISH	0	0	0	0	1	3	2	0	1	7	0.009
SHORTHEAD REDHORSE	0	0	2	0	0	1	1	0	0	4	0.005
BLUNTNOSE MINNOW	0	0	0	0	0	0	3	0	0	3	0.004
SILVER REDHORSE	0	0	0	0	0	1	2	0	0	3	0.004
MOTTLED SCULPIN	0	0	0	0	0	0	0	0	1	1	0.001
GREEN SUNFISH	0	0	0	0	0	0	0	1	0	1	0.001
LAKE STURGEON	0	1	0	0	0	0	0	0	0	1	0.001
TOTALS	493	5967	5674	8357	22219	6900	6403	20731	1453	78197	

1980

SPECIES	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	% OF TOTAL
	MONTHS										
RAINBOW SMELT	2089	3327	3502	616	17865	3103	2978	1644	1573	36697	43.601
ALEWIFE	152	376	4142	1857	2042	3880	3291	198	55	15993	19.002
SPOTTAIL SHINER	35	565	3889	4667	577	3002	2175	236	127	15273	18.146
UNIDENTIFIED COREGONINAE	2	741	3070	710	595	848	1387	687	894	8934	10.615
TROUT-PERCH	31	470	520	626	429	610	149	45	5	2885	3.428
YELLOW PERCH	25	15	42	230	513	787	86	12	5	1715	2.038
LAKE TROUT	16	54	28	0	10	61	211	125	1	506	0.601
WHITE SUCKER	0	42	58	36	92	120	30	14	0	392	0.466
JOHNNY DARTER	22	80	37	21	16	54	29	20	34	313	0.372
EMERALD SHINER	1	0	0	0	80	107	31	28	0	247	0.293
NINESPINE STICKLEBACK	4	98	100	24	9	0	0	0	1	236	0.280
LONGNOSE SUCKER	8	35	21	10	18	34	26	14	0	166	0.197
SLIMY SCULPIN	78	44	18	7	1	1	0	2	12	163	0.194
ROUND WHITEFISH	16	6	8	8	9	7	31	27	4	116	0.138
GIZZARD SHAD	2	0	1	22	51	6	25	4	0	111	0.132
CHINOOK SALMON	3	3	59	3	8	21	1	1	0	99	0.118
COHO SALMON	5	58	0	1	1	9	0	1	0	75	0.089
LAKE WHITEFISH	2	3	13	1	36	17	1	2	0	75	0.089
BROWN TROUT	21	5	16	0	0	2	3	3	0	50	0.059
RAINBOW TROUT	1	1	0	0	1	6	7	10	0	26	0.031
GOLDEN SHINER	0	0	0	0	0	0	15	0	0	15	0.018
COMMON CARP	1	0	1	5	2	0	3	2	0	14	0.017
SILVER REDHORSE	0	0	1	2	6	5	0	0	0	14	0.017
CHANNEL CATFISH	1	0	0	0	5	4	0	0	0	10	0.012
SHORTHEAD REDHORSE	0	0	2	0	3	1	1	0	0	7	0.008
BURBOT	1	0	0	0	0	0	3	1	0	5	0.006
MOTTLED SCULPIN	1	0	1	0	1	0	1	1	0	5	0.006
GOLDEN REDHORSE	0	0	2	0	0	2	0	0	0	4	0.005
LONGNOSE DACE	0	0	0	3	0	0	0	0	0	3	0.004
WALLEYE	0	0	0	0	0	0	2	1	0	3	0.004
CENTRAL MUDMINNOW	0	2	0	0	0	0	0	0	0	2	0.002
YELLOW BULLHEAD	0	0	0	2	0	0	0	0	0	2	0.002
QUILLBACK	0	0	0	0	1	0	1	0	0	2	0.002
DEEPWATER SCULPIN	0	2	0	0	0	0	0	0	0	2	0.002
BLACK CRAPPIE	0	0	1	0	0	0	0	0	0	1	0.001
FRESHWATER DRUM	0	0	0	0	0	0	0	1	0	1	0.001
LAKE HERRING	0	0	1	0	0	0	0	0	0	1	0.001
NORTHERN PIKE	0	0	0	0	0	0	1	0	0	1	0.001
BLUEGILL	0	0	0	0	0	0	1	0	0	1	0.001
TOTALS	2517	5927	15533	8851	22371	12687	10489	3079	2711	84165	

abundant inshore. The exception was 1979, when December trawls yielded 200 fish which was the highest monthly total catch during that year of cold water temperatures.

Trout-perch were the fourth- or fifth-most abundant fish collected during the 4-yr study (Table 10). Total catch varied from a high of 2885 fish in 1980 (3.4% of the total catch) to a low of 893 in 1977 (1.1% of the catch). The low 1977 catch was probably due to reduced fishing during the early part of the year when large catches were usually taken. Trout-perch have an extended spawning season and seem to prefer moderately warm water, so they were caught in large numbers over most of the spring and summer (May-August). The largest catch of trout-perch, in 1980, was attributed to a year of good survival for adults and yearlings, which were dominant age-groups in our catches. In prior years their contribution to yearly total catch was sporadic, with only one of the age-groups abundant.

The catch of fish in the subfamily Coregoninae (Unidentified Coregoninae), which are believed to be mostly bloaters, *Coregonus hoyi*, rose steadily from 460 fish in 1977 (1% of catch) to 8934 fish in 1980 (11% of the catch). This increase has been a lake-wide phenomenon and is attributed to the banning of gill nets for commercial harvest of bloaters and a decline in alewife abundance. The Coregoninae were the fourth- to sixth-most abundant fish collected during our study years. The catch was generally comprised of three groups of fish which varied in abundance over the study years. Most were YOY in the 60-80-mm length range.

Among remaining species, lake trout was one that showed a large increase in catch from 258 and 222 in 1978 and 1979 respectively to 507 in 1980. The large increase in 1980 may be a manifestation of the attraction of lake trout to the newly laid riprap in the vicinity of the plant in fall 1979-1980. However, no large differences in catch between reference (south) and plant transects were found for 1980 (see RESULTS AND DISCUSSION, Lake Trout).

Many other species were collected in lesser numbers, including some that are known to be attracted to riprap or a thermal plume. When catches of johnny darter and slimy sculpin (species which commonly inhabit riprap areas) were examined, we found no increased catch over the 4 yr. Two other species, carp and gizzard shad, are usually found in greater numbers around thermal plumes. To date, however, no evidence of such an attraction was apparent in our study area, but the offshore thermal plume during 1980 was probably small (Units 1 and 2 only) and intermittent. The catches in 1981 should establish whether significant attraction is occurring, since Unit 3 will be in operation.

The lake sturgeon, a threatened species, is present in the plant vicinity as two were collected, one in 1977 and one in 1978. Both were released. We do not expect the plant will have any impact on this rare species.

The number of each species collected was separated by gear type (Tables 11, 12, 13, 14). The catch in each gear of all species pooled over years was highest for trawls (68.2% - 226,260), followed by seines (21.2% - 70,396),

bottom gill nets (8.8% - 29,135) and surface gill nets (1.8% - 6163). Trawls were statistically the most effective gear for making comparisons, because among gear, trawl catches exhibited the least variability. As could be expected, surface gill nets were the least efficient gear, catching the fewest fish overall. In 1977, seines caught the most fish, while for remaining years trawls caught the greatest number. Examination of total catch by species and gear within a given year showed that for 1977, alewives were the most frequently seined fish (36,784). In 1978 spottail shiners were the dominant fish (6873) in seines followed by alewives (2999). For both 1979 and 1980, alewives were the most frequently seined fish. Among fish caught in surface gill nets, attesting to their habitation of surface waters at 6 and 9 m, alewives were by far the most frequently caught fish in all 4 yr. Alewives are known to migrate to surface waters during the night. For bottom gill nets, alewives (1977) and spottail shiners (1978-1980) were the most commonly caught fish. Trawl catches reflected total catch trends. Alewives were most frequently caught in 1977-1978, while rainbow smelt assumed dominance in trawl hauls in the latter 2 yr. However, total catch is not the only criterion on which we evaluate the use of four types of gear. Each type has its own particular bias and strong points. For example, although surface gill nets catch the least number of fish, it is the only gear which will fish directly in the thermal plume, as most plumes float on surface waters. All our other gear fish bottom waters.

In 1977 seined alewives (36,784) and trawled alewives and smelt (15,191 and 12,725 respectively) comprised the largest percentage of the total catch (Tables 11-14). This pattern was not much different in 1978 when trawled alewives and smelt (36,528 and 24,077) were the largest proportion of the total catch and in 1979 when trawls caught 23,127 alewives and 27,815 smelt. In 1980, the number of major species comprising most of the total catch increased, but all were collected primarily by trawls. They included: 35,238 smelt; 8834 spottails and 8043 unidentified Coregoninae. More detailed discussion of catch differences and their significance will be presented in the individual fish sections under RESULTS AND DISCUSSION.

The densities and distributions of larval fish species are discussed under individual species accounts. To give a more general overview of distribution of all larvae (all species combined) with depth, we calculated a mean density for each station and sampling period, pooled over diel periods, strata and replicates (in the case of beach tows) for each year 1977-1980 (Tables 15-18). These data should be useful for giving times and depths of greatest occurrence of larval fish in the vicinity of the Campbell Plant. Yearly variability of total larvae was high. In 1980, catches were highest, with five incidences of densities over 10,000/1000 m^3, very few catches of no larvae and remaining catches in the 1000-2000/1000 m^3 range. As noted previously, 1980 was a warm year, with no major upwellings occurring during sampling periods, or for the larval fish season. Thus, warm years and infrequent upwellings are major physical factors controlling strength of larval fish production in eastern Lake Michigan. During 1977-1979, larval fish densities were in the 1000-2000/1000 m^3 range, with few exceptionally high catches.

Table 11. Summary of all fish species caught by seines during June to November 1977 and April to November 1978-1980 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan.

1977

SPECIES	MONTHS JUN	JUL	AUG	SEP	OCT	NOV	SUM	% OF TOTAL
ALEWIFE	1110	5077	11218	14880	2856	1643	36784	83.655
SPOTTAIL SHINER	435	1166	1298	3634	52	24	6609	15.030
YELLOW PERCH	0	31	14	285	0	2	332	0.755
RAINBOW SMELT	19	5	16	29	5	1	75	0.171
GIZZARD SHAD	0	3	2	47	13	4	69	0.157
COHO SALMON	47	0	0	0	0	0	47	0.107
BROWN TROUT	9	1	0	0	0	0	10	0.023
UNIDENTIFIED COREGONINAE	0	0	0	7	0	0	7	0.016
TROUT-PERCH	4	0	2	0	0	0	6	0.014
COMMON CARP	0	4	0	1	0	0	5	0.011
BLUEGILL	0	0	0	0	4	0	4	0.009
RAINBOW TROUT	0	0	0	1	3	0	4	0.009
SILVER REDHORSE	0	4	0	0	0	0	4	0.009
LONGNOSE DACE	0	0	0	0	1	2	3	0.007
LAKE TROUT	0	0	0	2	1	0	3	0.007
WHITE SUCKER	0	2	0	0	0	0	2	0.005
BROOK SILVERSIDE	0	0	0	0	1	0	1	0.002
JOHNNY DARTER	0	0	0	0	0	1	1	0.002
LAKE STURGEON	0	1	0	0	0	0	1	0.002
EMERALD SHINER	0	0	1	0	0	0	1	0.002
PUMPKINSEED	0	0	0	0	1	0	1	0.002
CHINOOK SALMON	1	0	0	0	0	0	1	0.002
NINESPINE STICKLEBACK	1	0	0	0	0	0	1	0.002
TOTALS	1626	6294	12551	18886	2937	1677	43971	

1978

SPECIES	MONTHS APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	SUM	% OF TOTAL
SPOTTAIL SHINER	11	146	1248	2495	2731	213	19	10	6873	62.957
ALEWIFE	3	9	55	79	1258	1077	509	9	2999	27.471
RAINBOW SMELT	73	379	119	3	3	5	3	7	592	5.423
YELLOW PERCH	0	0	2	113	13	0	0	1	129	1.182
TROUT-PERCH	8	19	28	3	15	0	0	5	78	0.714
WHITE SUCKER	0	4	1	39	13	0	0	0	57	0.522
EMERALD SHINER	0	0	3	0	16	27	0	4	50	0.458
COHO SALMON	0	5	17	14	0	0	0	0	36	0.330
CHINOOK SALMON	0	0	11	5	0	0	0	0	16	0.147
BLUNTNOSE MINNOW	0	0	0	0	1	13	0	0	14	0.128
BROWN TROUT	5	6	1	1	0	0	0	0	13	0.119
NINESPINE STICKLEBACK	5	2	4	0	0	0	0	0	11	0.101
LAKE TROUT	0	0	0	0	0	0	9	1	10	0.092
WALLEYE	0	0	0	0	6	0	0	0	6	0.055
GIZZARD SHAD	0	0	0	0	0	3	3	0	6	0.055
COMMON CARP	2	1	0	0	2	0	0	0	5	0.046
UNIDENTIFIED COREGONINAE	0	0	2	0	0	3	0	0	5	0.046
JOHNNY DARTER	0	0	2	0	2	0	0	0	4	0.037
SLIMY SCULPIN	1	1	0	1	0	0	0	0	3	0.027
RAINBOW TROUT	2	1	0	0	0	0	0	0	3	0.027
LONGNOSE SUCKER	0	1	0	0	0	1	0	0	2	0.018
GOLDFISH	0	0	0	1	0	0	0	0	1	0.009
SMALLMOUTH BASS	0	0	0	0	1	0	0	0	1	0.009
FATHEAD MINNOW	0	0	0	0	1	0	0	0	1	0.009
QUILLBACK	0	0	1	0	0	0	0	0	1	0.009
BLUEGILL	0	0	0	0	0	1	0	0	1	0.009
TOTALS	110	574	1494	2754	4062	1343	543	37	10917	

Table 11. Continued.

1979

SPECIES	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	SUM	% OF TOTAL
	MONTHS									
ALEWIFE	0	0	1	46	2155	160	220	5	2587	41.122
SPOTTAIL SHINER	13	171	364	1017	209	111	6	4	1895	30.122
RAINBOW SMELT	4	1321	0	178	66	82	6	1	1658	26.355
TROUT-PERCH	3	44	0	0	0	1	1	0	49	0.779
CHINOOK SALMON	2	16	14	6	0	0	0	0	38	0.604
UNIDENTIFIED COREGONINAE	0	0	4	0	0	6	0	0	10	0.159
GIZZARD SHAD	1	0	1	1	0	2	4	0	9	0.143
BROWN TROUT	1	0	3	1	1	0	1	0	7	0.111
EMERALD SHINER	3	2	0	0	2	0	0	0	7	0.111
NINESPINE STICKLEBACK	2	3	0	1	0	0	0	0	6	0.095
RAINBOW TROUT	1	0	0	0	0	0	4	1	6	0.095
COHO SALMON	0	4	0	0	0	0	1	0	5	0.079
LONGNOSE SUCKER	0	0	1	4	0	0	0	0	5	0.079
YELLOW PERCH	1	0	1	0	0	0	2	0	4	0.064
BLUNTNOSE MINNOW	0	0	0	0	0	0	3	0	3	0.048
SLIMY SCULPIN	1	0	0	0	0	0	0	0	1	0.016
WHITE SUCKER	0	0	0	1	0	0	0	0	1	0.016
TOTALS	32	1561	389	1255	2433	362	248	11	6291	

1980

SPECIES	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	SUM	% OF TOTAL
	MONTHS									
ALEWIFE	1	46	1336	283	1804	2663	127	0	6260	67.918
SPOTTAIL SHINER	3	182	173	284	297	655	74	2	1670	18.119
RAINBOW SMELT	2	330	91	0	48	96	6	4	577	6.260
UNIDENTIFIED COREGONINAE	0	0	16	0	0	236	0	0	252	2.734
EMERALD SHINER	1	0	0	0	80	107	31	28	247	2.680
CHINOOK SALMON	0	2	52	1	0	0	0	0	55	0.597
COHO SALMON	0	54	0	0	0	0	0	0	54	0.586
YELLOW PERCH	0	0	0	0	7	6	20	0	33	0.358
GIZZARD SHAD	0	0	0	0	26	0	2	0	28	0.304
GOLDEN SHINER	0	0	0	0	0	0	15	0	15	0.163
TROUT-PERCH	0	4	1	0	0	1	3	1	10	0.108
WHITE SUCKER	0	0	2	2	0	0	1	0	5	0.054
NINESPINE STICKLEBACK	0	2	0	0	0	0	0	0	2	0.022
LONGNOSE DACE	0	0	0	2	0	0	0	0	2	0.022
LAKE WHITEFISH	0	0	1	0	0	0	0	0	1	0.011
JOHNNY DARTER	0	0	0	0	0	1	0	0	1	0.011
FRESHWATER DRUM	0	0	0	0	0	0	0	1	1	0.011
RAINBOW TROUT	0	1	0	0	0	0	0	0	1	0.011
BLACK CRAPPIE	0	0	1	0	0	0	0	0	1	0.011
BROWN TROUT	0	1	0	0	0	0	0	0	1	0.011
BLUEGILL	0	0	0	0	0	0	1	0	1	0.011
TOTALS	7	622	1673	572	2262	3765	280	36	9217	

Table 12. Summary of all fish species caught by surface gill nets during June to November 1977 and April to November 1978-1980 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan.

1977

SPECIES	MONTHS JUN	JUL	AUG	SEP	OCT	NOV	SUM	% OF TOTAL
ALEWIFE	278	251	0	205	0	0	734	86.967
RAINBOW SMELT	0	1	0	34	0	0	35	4.147
LAKE TROUT	0	12	0	17	0	0	29	3.436
GIZZARD SHAD	0	0	0	0	0	19	19	2.251
BROWN TROUT	0	2	0	4	0	4	10	1.185
UNIDENTIFIED COREGONINAE	0	7	0	0	0	0	7	0.829
WHITE SUCKER	0	1	0	2	0	0	3	0.355
CHINOOK SALMON	0	0	0	1	0	2	3	0.355
COHO SALMON	0	0	0	2	0	0	2	0.237
SPOTTAIL SHINER	0	1	0	0	0	0	1	0.118
LONGNOSE SUCKER	0	1	0	0	0	0	1	0.118
TOTALS	278	276	265	0	25	0	844	

1978

SPECIES	MONTHS APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	SUM	% OF TOTAL
ALEWIFE	15	370	254	758	177	131	7	0	1712	83.026
SPOTTAIL SHINER	0	28	166	7	1	0	0	0	202	9.796
RAINBOW SMELT	5	66	2	0	1	1	2	0	77	3.734
LAKE TROUT	1	9	1	0	0	0	20	0	31	1.503
GIZZARD SHAD	0	0	0	0	12	3	1	0	16	0.776
COHO SALMON	1	0	1	1	0	3	1	0	7	0.339
BROWN TROUT	0	1	3	1	0	1	0	0	6	0.291
CHINOOK SALMON	3	0	1	1	0	0	0	0	5	0.242
CHANNEL CATFISH	0	0	0	0	1	1	0	0	2	0.097
WHITE SUCKER	0	1	0	0	0	0	0	0	1	0.048
LAKE WHITEFISH	0	1	0	0	0	0	0	0	1	0.048
TROUT-PERCH	0	1	0	0	0	0	0	0	1	0.048
LONGNOSE SUCKER	0	1	0	0	0	0	0	0	1	0.048
TOTALS	25	478	428	768	192	140	31	0	2062	

1979

SPECIES	MONTHS APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	SUM	% OF TOTAL
ALEWIFE	0	339	363	493	170	190	0	0	1555	86.197
RAINBOW SMELT	0	9	2	39	30	54	1	0	135	7.483
LAKE TROUT	0	1	2	2	0	2	14	6	27	1.497
BROWN TROUT	0	8	1	3	1	5	0	1	19	1.053
SPOTTAIL SHINER	0	1	3	0	2	12	0	0	18	0.998
RAINBOW TROUT	8	1	0	0	0	0	1	5	15	0.831
CHINOOK SALMON	0	2	0	3	1	4	0	1	11	0.610
UNIDENTIFIED COREGONINAE	0	0	0	7	0	0	0	0	7	0.388
COHO SALMON	2	0	0	0	0	1	2	0	5	0.277
TROUT-PERCH	0	0	0	0	0	5	0	0	5	0.277
YELLOW PERCH	0	0	0	0	0	5	0	0	5	0.277
WHITE SUCKER	0	0	0	2	0	0	0	0	2	0.111
TOTALS	10	361	371	549	204	278	18	13	1804	

1980

SPECIES	MONTHS APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	SUM	% OF TOTAL
ALEWIFE	0	83	472	464	46	81	0	1	1147	78.940
RAINBOW SMELT	6	14	22	0	18	56	0	0	116	7.983
LAKE TROUT	0	0	2	0	0	0	60	10	72	4.955
SPOTTAIL SHINER	0	0	0	24	21	1	0	0	46	3.166
YELLOW PERCH	0	0	0	0	16	0	0	0	16	1.101
RAINBOW TROUT	0	0	0	0	0	3	3	9	15	1.032
CHINOOK SALMON	0	1	1	0	1	8	1	1	13	0.895
COHO SALMON	3	1	0	0	0	7	0	0	11	0.757
BROWN TROUT	0	0	3	0	0	1	0	2	6	0.413
UNIDENTIFIED COREGONINAE	0	0	4	0	1	0	0	0	5	0.344
CHANNEL CATFISH	0	0	0	0	2	2	0	0	4	0.275
WHITE SUCKER	0	0	0	0	0	1	0	0	1	0.069
LONGNOSE SUCKER	0	0	0	0	1	0	0	0	1	0.069
TOTALS	9	99	504	488	106	160	64	23	1453	

Table 13. Summary of all fish species caught by bottom gill nets during June to December 1977 and April to November 1978-1980 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan.

1977

SPECIES	MONTHS JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	% OF TOTAL
ALEWIFE	67	327	325	435	0	1	0	1155	35.517
YELLOW PERCH	58	111	368	146	1	37	0	721	22.171
SPOTTAIL SHINER	26	40	144	349	0	31	0	590	18.143
WHITE SUCKER	2	48	150	82	0	4	1	287	8.825
LAKE TROUT	2	42	1	101	0	18	0	164	5.043
GIZZARD SHAD	0	0	12	3	0	71	0	86	2.645
RAINBOW SMELT	0	3	7	53	0	0	0	63	1.937
UNIDENTIFIED COREGONINAE	34	16	0	5	0	0	0	55	1.691
LONGNOSE SUCKER	0	15	13	6	0	0	0	34	1.046
TROUT-PERCH	0	2	8	3	0	21	0	34	1.046
BROWN TROUT	2	3	3	11	0	10	0	29	0.892
SILVER REDHORSE	0	2	2	3	0	1	0	8	0.246
CHANNEL CATFISH	0	0	6	0	0	0	0	6	0.185
ROUND WHITEFISH	0	1	0	3	0	2	0	6	0.185
COHO SALMON	0	0	0	1	0	4	0	5	0.154
RAINBOW TROUT	0	0	0	0	0	4	0	4	0.123
LAKE WHITEFISH	0	1	0	1	0	0	0	2	0.062
COMMON CARP	0	0	2	0	0	0	0	2	0.062
SHORTHEAD REDHORSE	0	0	1	0	0	0	0	1	0.031
TOTALS	191	611	1042	1202	1	204	1	3252	

1978

SPECIES	MONTHS APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	SUM	% OF TOTAL
SPOTTAIL SHINER	7	166	1454	1718	262	202	53	39	3901	42.601
ALEWIFE	3	488	114	2397	84	219	11	62	3378	36.890
RAINBOW SMELT	322	143	7	16	12	61	8	13	582	6.356
YELLOW PERCH	5	1	3	23	176	199	6	13	426	4.652
WHITE SUCKER	0	33	28	29	65	78	5	11	249	2.719
LAKE TROUT	30	23	18	10	5	2	67	52	207	2.261
GIZZARD SHAD	0	0	0	1	53	45	7	18	124	1.354
BROWN TROUT	36	16	16	9	4	4	3	7	95	1.037
LONGNOSE SUCKER	1	29	9	16	1	7	2	3	68	0.743
TROUT-PERCH	0	3	1	0	2	9	6	24	45	0.491
COHO SALMON	1	2	0	1	2	4	2	1	13	0.142
UNIDENTIFIED COREGONINAE	0	0	0	3	7	0	0	1	11	0.120
JOHNNY DARTER	0	0	0	0	0	0	8	0	8	0.087
ROUND WHITEFISH	1	1	2	0	2	0	1	1	8	0.087
COMMON CARP	0	0	0	0	5	2	0	0	7	0.076
LAKE WHITEFISH	4	0	1	0	1	0	0	0	6	0.066
CHINOOK SALMON	1	1	1	0	0	2	0	1	6	0.066
RAINBOW TROUT	0	1	0	0	0	0	1	4	6	0.066
SILVER REDHORSE	0	0	0	0	0	4	0	0	4	0.044
GOLDEN REDHORSE	0	0	0	1	0	3	0	0	4	0.044
QUILLBACK	0	0	0	0	2	1	0	0	3	0.033
NORTHERN PIKE	0	0	0	0	1	0	1	0	2	0.022
SHORTHEAD REDHORSE	0	0	1	0	0	0	0	0	1	0.011
CHANNEL CATFISH	0	0	0	0	0	1	0	0	1	0.011
FRESHWATER DRUM	0	0	0	0	0	1	0	0	1	0.011
SMALLMOUTH BASS	0	0	0	0	0	1	0	0	1	0.011
TOTALS	411	907	1655	4224	684	845	181	250	9157	

Table 13. Continued.

1979

SPECIES	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	SUM	% OF TOTAL
	MONTHS									
SPOTTAIL SHINER	17	397	679	664	401	217	220	75	2670	45.908
ALEWIFE	0	87	510	132	248	242	2	0	1221	20.994
RAINBOW SMELT	8	36	5	0	91	276	4	0	420	7.221
WHITE SUCKER	0	47	42	110	40	156	7	4	406	6.981
UNIDENTIFIED COREGONINAE	0	0	28	183	2	13	0	1	227	3.903
YELLOW PERCH	5	5	17	32	39	78	6	36	218	3.748
LONGNOSE SUCKER	0	47	12	93	3	29	11	3	198	3.404
LAKE TROUT	9	11	6	15	13	22	73	27	176	3.026
TROUT-PERCH	1	10	11	7	0	11	10	39	89	1.530
BROWN TROUT	26	8	8	5	2	7	4	0	60	1.032
ROUND WHITEFISH	2	3	4	0	0	6	17	5	37	0.636
LAKE WHITEFISH	0	0	9	8	0	3	0	0	20	0.344
CHINOOK SALMON	2	1	1	2	1	6	1	1	15	0.258
GIZZARD SHAD	2	1	0	0	2	0	9	1	15	0.258
GOLDEN REDHORSE	0	0	2	7	0	0	1	0	10	0.172
COMMON CARP	2	0	1	0	0	1	2	1	7	0.120
RAINBOW TROUT	7	0	0	0	0	0	0	0	7	0.120
CHANNEL CATFISH	0	0	0	0	1	3	2	0	6	0.103
COHO SALMON	2	0	0	0	0	3	0	0	5	0.086
SHORTHEAD REDHORSE	0	0	2	0	0	1	1	0	4	0.069
SILVER REDHORSE	0	0	0	0	0	1	2	0	3	0.052
SLIMY SCULPIN	1	0	0	0	0	0	0	0	1	0.017
LAKE STURGEON	0	1	0	0	0	0	0	0	1	0.017
TOTALS	84	654	1337	1258	843	1075	372	193	5816	

1980

SPECIES	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	SUM	% OF TOTAL
	MONTHS									
SPOTTAIL SHINER	11	138	924	2147	208	1033	204	58	4723	43.291
ALEWIFE	5	50	1235	960	115	184	20	1	2570	23.556
YELLOW PERCH	8	5	13	172	266	335	7	8	814	7.461
RAINBOW SMELT	240	17	39	0	187	224	50	[illegible]	766	7.021
UNIDENTIFIED COREGONINAE	0	7	401	15	29	182	0	0	634	5.811
WHITE SUCKER	0	42	55	30	91	119	29	14	380	3.483
LAKE TROUT	15	7	15	0	5	61	150	115	368	3.373
TROUT-PERCH	2	16	10	10	8	29	67	18	160	1.467
LONGNOSE SUCKER	8	35	20	2	16	34	26	14	155	1.421
ROUND WHITEFISH	10	3	5	0	4	2	27	26	77	0.706
GIZZARD SHAD	2	0	1	22	25	6	7	4	67	0.614
LAKE WHITEFISH	1	0	9	0	32	15	0	0	57	0.522
BROWN TROUT	21	4	13	0	0	1	3	0	42	0.385
CHINOOK SALMON	2	0	0	1	6	13	0	0	22	0.202
SILVER REDHORSE	0	0	1	2	6	5	0	0	14	0.128
COMMON CARP	1	0	1	5	2	0	2	2	13	0.119
RAINBOW TROUT	1	0	0	0	1	3	4	1	10	0.092
COHO SALMON	2	3	0	1	0	2	0	1	9	0.082
SHORTHEAD REDHORSE	0	0	2	0	3	1	1	0	7	0.064
CHANNEL CATFISH	1	0	0	0	3	2	0	0	6	0.055
GOLDEN REDHORSE	0	0	2	0	0	2	0	0	4	0.037
BURBOT	1	0	0	0	0	0	2	1	4	0.037
WALLEYE	0	0	0	0	0	0	2	1	3	0.027
YELLOW BULLHEAD	0	0	0	2	0	0	0	0	2	0.018
QUILLBACK	0	0	0	0	1	0	1	0	2	0.018
NORTHERN PIKE	0	0	0	0	0	0	1	0	1	0.009
TOTALS	331	327	2746	3369	1008	2253	603	273	10910	

Table 14. Summary of all fish species caught by trawls during June to December 1977 and April to December 1978-1980 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan.

1977

SPECIES	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	% OF TOTAL
	MONTHS								
ALEWIFE	743	195	2137	794	6557	4765	0	15191	49.740
RAINBOW SMELT	1046	545	7395	2590	348	69	732	12725	41.665
TROUT-PERCH	322	219	119	130	36	22	5	853	2.793
SPOTTAIL SHINER	98	0	2	38	314	33	198	683	2.236
UNIDENTIFIED COREGONINAE	39	23	4	26	234	61	4	391	1.284
JOHNNY DARTER	116	13	17	73	68	9	1	297	0.972
YELLOW PERCH	34	5	66	32	6	4	54	201	0.658
NINESPINE STICKLEBACK	86	16	11	14	3	2	0	132	0.432
SLIMY SCULPIN	12	5	0	0	3	1	23	44	0.144
LAKE WHITEFISH	8	1	0	0	0	0	0	9	0.026
LAKE TROUT	2	2	0	0	0	0	1	5	0.016
MOTTLED SCULPIN	4	0	0	0	0	0	0	4	0.013
ROUND WHITEFISH	0	0	0	0	1	0	1	2	0.007
WHITE SUCKER	1	0	1	0	0	0	0	2	0.007
BURBOT	0	0	0	0	0	0	1	1	0.003
LONGNOSE SUCKER	0	0	0	0	0	1	0	1	0.003
TOTALS	2511	1024	9752	3697	7570	4967	1020	30541	

1978

SPECIES	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	% OF TOTAL
	MONTHS										
ALEWIFE	0	13	143	320	64	429	8778	26775	6	36528	53.056
RAINBOW SMELT	693	3458	2364	6633	6200	2212	1103	1063	351	24077	34.971
UNIDENTIFIED COREGONINAE	0	5	189	537	196	16	1666	478	18	3105	4.510
SPOTTAIL SHINER	8	85	215	2	477	630	173	93	105	1788	2.597
TROUT-PERCH	3	297	423	354	383	195	16	27	19	1717	2.494
YELLOW PERCH	3	2	3	6	113	340	22	5	29	523	0.760
NINESPINE STICKLEBACK	0	31	139	151	80	0	2	0	0	403	0.585
JOHNNY DARTER	0	29	46	36	87	56	54	36	6	350	0.508
SLIMY SCULPIN	60	128	13	31	9	0	0	1	34	276	0.401
GIZZARD SHAD	0	0	0	0	0	7	4	0	32	43	0.062
WHITE SUCKER	0	1	0	10	0	1	0	0	0	12	0.017
LAKE TROUT	0	0	3	5	2	0	0	0	0	10	0.015
BURBOT	0	0	0	0	0	1	0	2	1	0	4	0.006
LONGNOSE SUCKER	0	0	0	0	1	1	0	0	0	2	0.003
ROUND WHITEFISH	0	0	0	0	1	0	0	0	1	2	0.003
CHINOOK SALMON	0	0	0	1	0	1	0	0	0	2	0.003
LAKE WHITEFISH	0	0	1	1	0	0	0	0	0	2	0.003
COMMON CARP	0	0	0	0	0	0	1	0	0	1	0.001
BLUNTNOSE MINNOW	0	0	0	0	0	0	0	1	0	1	0.001
BLUEGILL	0	0	0	0	0	0	1	0	0	1	0.001
WALLEYE	0	0	0	0	0	0	0	0	1	1	0.001
TOTALS	767	4049	3539	8087	7614	3888	11822	28480	602	68848	

Table 14. Continued.

1979

SPECIES	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	% OF TOTAL
	MONTHS										
RAINBOW SMELT	293	2001	204	1891	17119	3863	588	1036	820	27815	43.268
ALEWIFE	0	23	325	6	130	601	4037	17841	164	23127	35.975
UNIDENTIFIED COREGONINAE	0	8	277	2540	403	410	392	1430	9	5469	8.507
SPOTTAIL SHINER	1	744	2396	67	703	77	557	140	206	4891	7.608
TROUT-PERCH	0	386	126	507	274	154	125	33	7	1612	2.508
JOHNNY DARTER	7	99	78	37	33	68	50	17	16	405	0.630
YELLOW PERCH	6	8	18	71	64	4	3	4	200	378	0.588
NINESPINE STICKLEBACK	0	52	143	166	1	0	1	3	1	367	0.571
SLIMY SCULPIN	59	65	2	1	1	0	1	1	24	154	0.240
LAKE TROUT	0	1	5	5	0	3	0	4	1	19	0.030
GIZZARD SHAD	0	0	0	0	0	0	8	1	2	11	0.017
ROUND WHITEFISH	0	1	0	0	2	0	2	1	1	7	0.011
LAKE WHITEFISH	0	0	0	4	1	2	0	0	0	7	0.011
LONGNOSE SUCKER	0	1	1	0	1	1	1	0	0	5	0.008
WHITE SUCKER	0	0	0	0	2	2	0	0	0	4	0.006
COMMON CARP	0	0	0	0	2	0	0	1	0	3	0.005
CHINOOK SALMON	0	2	1	0	0	0	0	0	0	3	0.005
COHO SALMON	0	0	0	0	3	0	0	0	0	3	0.005
BROWN TROUT	0	0	1	0	0	0	0	1	0	2	0.003
RAINBOW TROUT	1	0	0	0	0	0	0	0	0	1	0.002
GREEN SUNFISH	0	0	0	0	0	0	0	1	0	1	0.002
MOTTLED SCULPIN	0	0	0	0	0	0	0	0	1	1	0.002
CHANNEL CATFISH	0	0	0	0	0	0	0	0	1	1	0.002
TOTALS	367	3391	3577	5295	18739	5185	5765	20514	1453	64286	

1980

SPECIES	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	% OF TOTAL
	MONTHS										
RAINBOW SMELT	1841	2966	3350	616	17612	2727	2922	1631	1573	35238	56.304
SPOTTAIL SHINER	21	245	2792	2212	51	1313	1897	176	127	8834	14.115
UNIDENTIFIED COREGONINAE	2	734	2649	695	565	430	1387	687	894	8043	12.851
ALEWIFE	146	197	1099	150	77	952	3144	196	55	6016	9.613
TROUT-PERCH	29	450	509	616	421	580	79	26	5	2715	4.338
YELLOW PERCH	17	10	29	58	224	446	59	4	5	852	1.361
JOHNNY DARTER	22	80	37	21	16	53	29	20	34	312	0.499
NINESPINE STICKLEBACK	4	96	100	24	9	0	0	0	1	234	0.374
SLIMY SCULPIN	78	44	18	7	1	1	0	2	12	163	0.260
LAKE TROUT	1	47	11	0	5	0	1	0	1	66	0.105
ROUND WHITEFISH	6	3	3	8	5	5	4	1	4	39	0.062
LAKE WHITEFISH	1	3	3	1	4	2	1	2	0	17	0.027
GIZZARD SHAD	0	0	0	0	0	0	16	0	0	16	0.026
LONGNOSE SUCKER	0	0	1	8	1	0	0	0	0	10	0.016
CHINOOK SALMON	1	0	6	1	1	0	0	0	0	9	0.014
WHITE SUCKER	0	0	1	4	1	0	0	0	0	6	0.010
MOTTLED SCULPIN	1	0	1	0	1	0	1	1	0	5	0.008
DEEPWATER SCULPIN	0	2	0	0	0	0	0	0	0	2	0.003
CENTRAL MUDMINNOW	0	2	0	0	0	0	0	0	0	2	0.003
LONGNOSE DACE	0	0	0	1	0	0	0	0	0	1	0.002
BURBOT	0	0	0	0	0	0	1	0	0	1	0.002
LAKE HERRING	0	0	1	0	0	0	0	0	0	1	0.002
COHO SALMON	0	0	0	0	1	0	0	0	0	1	0.002
COMMON CARP	0	0	0	0	0	0	1	0	0	1	0.002
BROWN TROUT	0	0	0	0	0	0	0	1	0	1	0.002
TOTALS	2170	4879	10610	4422	18995	6509	9542	2747	2711	62585	

Larvae were most abundant during July and August of all years. In 1977, July was the peak month, while in 1979, August had highest catches. In 1978 and 1980, both July and August were months of maximum abundance. High densities of larvae were also recorded in June; densities were much higher than September levels, but lower than July and August collections.

The depth distribution of total larvae was in general inversely related to depth. A clear pattern of decreased densities with increasing depth was shown for peak larval abundance months in 1978 and 1979. In 1979, densities at beach to 3-m stations were high (some over 10,000/1000 m^3), while all densities at 6- to 15-m stations averaged less than 1000/1000 m^3. In 1978, a similar pattern was evident, but the densities at intermediate depths (3 to 9 m) were considerably higher with many values in the 2000/1000 m^3 range. At 12 and 15 m, average densities were mostly less than 500/1000 m^3. Trends in 1977 and 1980 were not as clear as the pattern established for 1978-1979, although the major deviation from the pattern was the occurrence of high average densities at intermediate depths. This occurred for two dates in 1980 at 6 and 9 m and at one date in 1977 at 12 m. Other than these sporadic occurrences of high densities at intermediate-depth stations, a similar trend of decreasing densities the deeper the station was observed.

MOST ABUNDANT SPECIES

Alewife

Introduction--

Over the 4 yr, the relative abundance of alewives has decreased from 68.5% of the total fish catch in 1977 to 19% of the total fish catch in 1980. Although there is an apparent precipitous decline over the 4 yr, a closer examination of the data reveals a more stable condition in adult populations. The total adult catches not adjusted for changes in sampling design were approximately 3650, 4858, 3180, and 4190 in 1977-1980 respectively. Year-to-year fluctuations in total catch (all age-groups combined) were primarily caused by extreme variability in catch of YOY and yearlings. Additionally, the increased catches of smelt and unidentified Coregoninae from 1977 to 1980 were the primary causes for the decreased percentage of alewives in our samples.

Adult alewives are generally most abundant in the area of the Campbell Plant in June and July, corresponding to times of intense spawning. It is likely that most spawning occurs at depths of 9 m or less. A major spawning peak in late June was indicated in all 4 yr resulting in highest densities of larval alewives in early July. The first occurrence of larvae in any year was related to the warming trend of Lake Michigan and occurred when water had warmed to approximately 12-15 C. Throughout June to August in any year cold-water upwellings caused temporary cessations in spawning which again ensued when the upwelling dissipated. YOY alewives along with yearlings and adults move offshore in autumn to depths outside our study area.

Table 15. Mean density (no./1000 m^3) of all species of larval fish at Lake Michigan stations near the J. H. Campbell Plant during 1977. Mean densities were calculated by averaging densities over all gear (sled and plankton net), all strata and diel periods (day and night). Number of samples is given in parentheses.

Station	Depth (m)	1977 31 May-4 Jun	17-22 Jun	7-9 Jul	13-14 Jul	20-28 Jul	15-19 Aug	21-23 Sep
Q	1	37 (4)	73 (4)	2961 (4)	*	7564 (6)	148 (5)	457 (6)
R	1	183 (4)	85 (4)	12972 (4)	4949 (4)	3171 (5)	741 (4)	*
I	1.5	0 (4)	0 (4)	*	2942 (2)	6906 (3)	31 (3)	10 (4)
J	3	0 (4)	0 (4)	*	1166 (4)	617 (5)	115 (5)	16 (5)
L	6	10 (8)	13 (8)	842 (8)	1079 (6)	48 (9)	241 (9)	12(10)
N	9	*	0(12)	*	1175 (6)	139(11)	126(11)	9(12)
O	12	*	0(12)	*	2118 (6)	128(11)	60(11)	10(12)
W	15	*	*	*	*	*	*	*
P	1	0 (4)	0 (4)	3320 (4)	*	4945 (6)	53 (5)	65 (6)
A	1.5	0 (2)	0 (2)	3729 (2)	*	665 (4)	7 (3)	90 (4)
B	3	0 (4)	44 (4)	4530 (4)	*	3486 (6)	79 (5)	74 (6)
C	6	4 (8)	61 (8)	1884 (8)	*	136(10)	71 (9)	9(10)
D	9	0(10)	42(10)	3996(10)	*	62(12)	47(11)	8(12)
E	12	0(10)	41(10)	2259(10)	*	60(12)	50(11)	7(12)
F	15	0(10)	27(10)	1472(10)	*	55(12)	67(11)	1(12)

*Sampling not performed

Table 16. Mean density (no./1000 m³) of all species of larval fish at Lake Michigan stations near the J. H. Campbell Plant during 1978. Mean densities were calculated by averaging densities over all gear (sled and plankton net), all strata and diel periods (day and night). Number of samples is given in parentheses.

		1978								
Station	Depth (m)	24-28 Apr	15-18 May	5-10 Jun	19-23 Jun	1-3 Jul	17-21 Jul	1-4 Aug	14-17 Aug	18-22 Sep
Q	1	477 (4)	543 (6)	1186 (5)	92 (6)	10046 (6)	108 (6)	2548 (6)	727 (6)	6 (6)
R	1	227 (4)	375 (4)	427 (4)	0 (4)	2669 (4)	0 (4)	539 (4)	1455 (4)	67 (4)
I	1.5	28 (3)	90 (4)	262 (3)	8 (4)	1460 (4)	105 (4)	1290 (4)	99 (4)	0 (4)
J	3	38 (6)	60 (6)	709 (5)	24 (6)	1661 (6)	140 (6)	700 (6)	98 (6)	0 (6)
L	6	8(10)	8(10)	258 (9)	15(10)	1546(10)	106(10)	472(10)	510(10)	4(10)
N	9	10(12)	7(12)	65(11)	9(12)	2147(12)	111(12)	170(11)	234(12)	2(12)
O	12	7(12)	6(12)	21(11)	12(12)	678(12)	144(12)	147(12)	66(12)	0(12)
W	15	7(11)	1(12)	6(11)	8(12)	420(12)	101(12)	43(12)	25(12)	0(12)
P	1	0 (6)	668 (6)	604 (5)	95 (6)	1039 (6)	1183 (6)	2955 (6)	844 (6)	0 (6)
A	1.5	44 (4)	296 (4)	82 (3)	23 (4)	994 (4)	67 (4)	2094 (4)	741 (4)	0 (4)
B	3	36 (6)	93 (6)	792 (5)	55 (6)	2188 (6)	122 (6)	2620 (6)	535 (5)	8 (6)
C	6	0(10)	10(10)	325 (9)	3(10)	1991 (9)	217(10)	1349(10)	741(10)	2(10)
D	9	5(12)	12(12)	47(11)	11(12)	1258(12)	222(12)	498(12)	103(12)	4(12)
E	12	9(12)	11(12)	19(11)	28(12)	789(12)	309(12)	144(12)	225(12)	0(12)
F	15	2(12)	7(12)	19(11)	16(12)	372(12)	99(12)	65(12)	331(12)	0(12)

Table 17. Mean density (no./1000 m^3) of all species of larval fish at Lake Michigan stations near the J. H. Campbell Plant during 1979. Mean densities were calculated by averaging densities over all gear (sled and plankton net), all strata and diel periods (day and night). Number of samples is given in parentheses.

Station	Depth (m)	1979 16-18 Apr	14-16 May	4-6 Jun	18-20 Jun	2-3 Jul	17-19 Jul	1-2 Aug	20-22 Aug	17-19 Sep
Q	1	4 (6)	705 (6)	249 (6)	86 (6)	1515 (6)	3075 (6)	10213 (6)	470 (6)	168 (6)
R	1	48 (4)	265 (4)	306 (6)	6440 (6)	1281 (6)	2990 (6)	9933 (6)	592 (6)	264 (6)
I	1.5	0 (4)	344 (4)	23 (4)	133 (4)	189 (4)	3129 (4)	11590 (4)	852 (4)	196 (4)
J	3	0 (6)	180 (6)	52 (6)	79 (6)	75 (6)	21 (6)	392 (6)	365 (6)	172 (6)
L	6	2(10)	45(10)	4(10)	38(10)	42(10)	19(10)	82(10)	196(10)	35(10)
N	9	1(12)	28(12)	16(12)	153(12)	41(12)	7(12)	77(12)	252(12)	20(12)
O	12	0(12)	23(11)	23(12)	116(12)	41(12)	6(12)	49(12)	334(12)	18(12)
W	15	0(12)	9(12)	7(12)	79(12)	23(12)	4(12)	68(12)	239(12)	14(12)
P	1	34 (6)	572 (6)	0 (6)	481 (6)	563 (6)	1440 (6)	11377 (6)	1773 (6)	131 (6)
A	1.5	0 (4)	449 (4)	19 (4)	2349 (4)	158 (4)	174 (4)	488 (4)	3337 (4)	118 (4)
B	3	0 (6)	72 (6)	13 (6)	46 (6)	160 (6)	81 (6)	157 (6)	1999 (6)	36 (6)
C	6	0(10)	43(10)	6(10)	26(10)	144(10)	9(10)	285(10)	211(10)	139(10)
D	9	2(12)	38(12)	23(12)	41(12)	26(12)	11(12)	204(12)	570(12)	32(12)
E	12	0(12)	18(11)	7(12)	69(12)	24(12)	8(12)	125(12)	462(12)	12(12)
F	15	3(12)	13(11)	8(12)	87(12)	12(12)	38(12)	99(12)	245(12)	24(12)

Table 18. Mean density (no./1000 m³) of all species of larval fish at Lake Michigan stations near the J. H. Campbell Plant during 1980. Mean densities were calculated by averaging densities over all gear (sled and plankton net), all strata and diel periods (day and night). Number of samples is given in parentheses.

Station	Depth (m)	1980 21-22 Apr	19-20 May	2-4 Jun	16-18 Jun	1-2 Jul	14-16 Jul	4-6 Aug	18-20 Aug	15-18 Sep
Q	1	250 (6)	237 (6)	51 (6)	813 (6)	7473 (6)	5703 (6)	8439 (6)	133 (6)	21 (6)
R	1	195 (6)	531 (6)	120 (6)	505 (6)	9864 (6)	11392 (6)	11643 (6)	1092 (6)	14 (6)
I	1.5	0 (4)	756 (4)	54 (4)	105 (4)	5053 (4)	8361 (4)	2343 (4)	693 (6)	22 (4)
J	3	0 (6)	126 (6)	0 (6)	33 (6)	1877 (6)	4980 (6)	725 (6)	44 (6)	8 (6)
L	6	0(10)	62(10)	6(10)	18(10)	4723(10)	3541(10)	978(10)	76(10)	4(10)
N	9	0(12)	22(12)	19(12)	47(12)	8500(12)	1708(12)	539(12)	105(12)	5(12)
O	12	0(12)	7(12)	10(12)	63(12)	4723(12)	807(12)	212(12)	52(12)	0(12)
W	15	0(12)	12(12)	24(12)	38(12)	2324(12)	1062(12)	57(12)	50(12)	0(12)
P	1	518 (6)	283 (6)	13 (6)	310 (6)	23807 (6)	14823 (6)	12952 (6)	148 (6)	0 (6)
A	1.5	0 (4)	888 (4)	0 (4)	170 (4)	2277 (4)	4984 (4)	4084 (4)	397 (4)	47 (4)
B	3	4 (6)	11 (6)	24 (6)	73 (6)	2389 (6)	4185 (6)	2940 (6)	238 (6)	4 (6)
C	6	0(10)	16(10)	6(10)	9(10)	7688(10)	3327(10)	354(10)	92(10)	4(10)
D	9	5(12)	0(12)	0(12)	15(12)	5118(12)	1433(12)	214(12)	36(12)	0(12)
E	12	2(12)	3(12)	8(12)	19(12)	2820(12)	1481(12)	118(12)	6(12)	0(12)
F	15	0(12)	1(12)	6(12)	31(12)	1003(12)	607(12)	234(12)	26(12)	0(12)

Larvae--

Our 4-yr studies documented that alewife was the most abundant species of larval fish present in the study area. Alewife larvae were most abundant from June to August, which might be expected from their reported May to August spawning time (Jude et al. 1979a, 1980). Previous studies (Jude et al. 1979a, 1980) suggest that larval alewives exhibit a "passive" stage during which little substantial horizontal determinate movement takes place, and during which larvae are carried passively by water currents. Since it is not known at which stage larval alewives begin to exhibit substantial directed horizontal movement in response to environmental factors, nor is it known at what critical current speeds this directed movement is possible, the extent to which ambient water currents determine the distribution of the larval population sampled is difficult to assess. It is possible that the net horizontal movement of larval alewives may be in the same direction as the prevailing water currents until the time of fin formation, as was found for mackerel (Sette 1943). In consideration of this possibility a study of their distribution requires an understanding of study area water currents.

The nearshore area is perhaps the most dynamic zone in Lake Michigan, and it is in this zone (a strip of approximately 10 km) that the main transfer of energy from the wind to the total basin takes place (Mortimer 1975). The current patterns in this nearshore area are extremely complex, being subject to a number of factors. Prominent among these factors are bottom topography and wind stress. The predominant currents in the area are shore-parallel, but under certain conditions the alongshore pattern is altered. One such aberration occurs when waves arrive at right angles to the beach which causes offshore rip currents (Bowen and Inman 1969). In addition to those currents produced more immediately by wind, there are a number of additional whole-basin internal waves which result from more prolonged wind stress; these also affect nearshore current patterns. These whole-basin wave motions are reviewed by Mortimer (1975).

One particular circulation pattern in Lake Michigan which has dramatic effects on the distribution and abundance of not only larval, but juvenile and adult fish, is the phenomenon of upwelling. Upwellings occur along the eastern shore of Lake Michigan with a north wind and along the western shore with a south wind (Mortimer 1975). Currents produced by these winds are deflected offshore by the Coriolis force resulting in the warmed surface water moving offshore and the cold hypolimnetic water moving shoreward and upward to replace it. Upwellings, on specific dates, can be the major driving force forging the distribution and abundance of larval alewives. This effect is examined in detail in the following text. Speculations regarding the time that particular groups of larvae hatched relative to our sampling periods are based on a mean hatching length of 3.8 mm and an average growth rate of 0.62 mm per day derived for Lake Huron stocks (Heinrich 1981).

Seasonal distribution--

April and May--Over the 4-yr period larval alewives were rarely encountered in Lake Michigan during April or May. The single larva caught in April 1978 was attributed to a late hatched larva from 1977. The only other occurrence was in May 1979 when very low (less than 65 larvae/1000 m^3) densities of alewife larvae were observed at one station in Lake Michigan which was evidence of only limited spawning at this time. Additional evidence for limited spawning and hatching of alewives in Lake Michigan during May is also given by Wells (1973, 1974) who found a few larval alewives in Lake Michigan near Saugatuck (25 km south of Port Sheldon) during late May 1972 and 1973. A few alewife larvae were also collected near Bridgman (108 km south of Port Sheldon) on 1 June 1974 (Jude et al. 1979b) further indicating limited spawning in May by alewives. Since the aforementioned study areas are all adjacent to a river system, it is also possible that early alewife spawning may have been occurring in the rivers resulting in some larvae being carried passively into Lake Michigan.

Early June--The occurrence of a major alewife hatch in early June of any year appears to be directly related to water temperature (Figs. 8-20). Threinen (1958) reported that alewives initiate spawning at water temperatures of 12.0-15.5 C. Water temperatures exceeding 15 C during early June 1978 evidently triggered substantial alewife spawning and hatching (Figs. 11-13). Mean densities of larval alewives at this time were highest at the beach to 3-m stations (Fig. 11) and exhibited substantial declines at the 6- to 15-m stations (Figs. 12-13). With the additional exception of early June 1979, when north transect beach and 3-m station water temperatures resulted in minimal alewife spawning and hatching (Fig. 14), mean densities exceeding 20 larvae/1000 m^3 were not observed in early June of other years.

It is probable that alewife spawning near Port Sheldon is generally minimal during early June unless inshore water warms to temperatures exceeding 12 C. Substantial late May-early June spawning and hatching occurred in only one (1978) of the 4 yr of the study.

Late June--The occurrence of larval alewives in late June was variable over the 4 yr. During 1977 and 1978 only limited hatching had occurred in late June as no mean densities exceeding 40 alewife larvae/1000 m^3 were observed (Figs. 8-13). During 1979 and 1980, mean densities of alewife larvae ranged from 73 to 100 larvae/1000 m^3 indicating a higher level of hatching activity compared with late June of 1977 and 1978 (Figs. 14-19). As during early June of all years, larvae captured in late June were primarily newly hatched (Figs. 8-19).

These data collectively indicate that spawning activity in the area of Port Sheldon is limited during the first half of June. Substantial spawning activity during early to mid-June would have resulted in higher larval alewife densities in the latter part of June of each year.

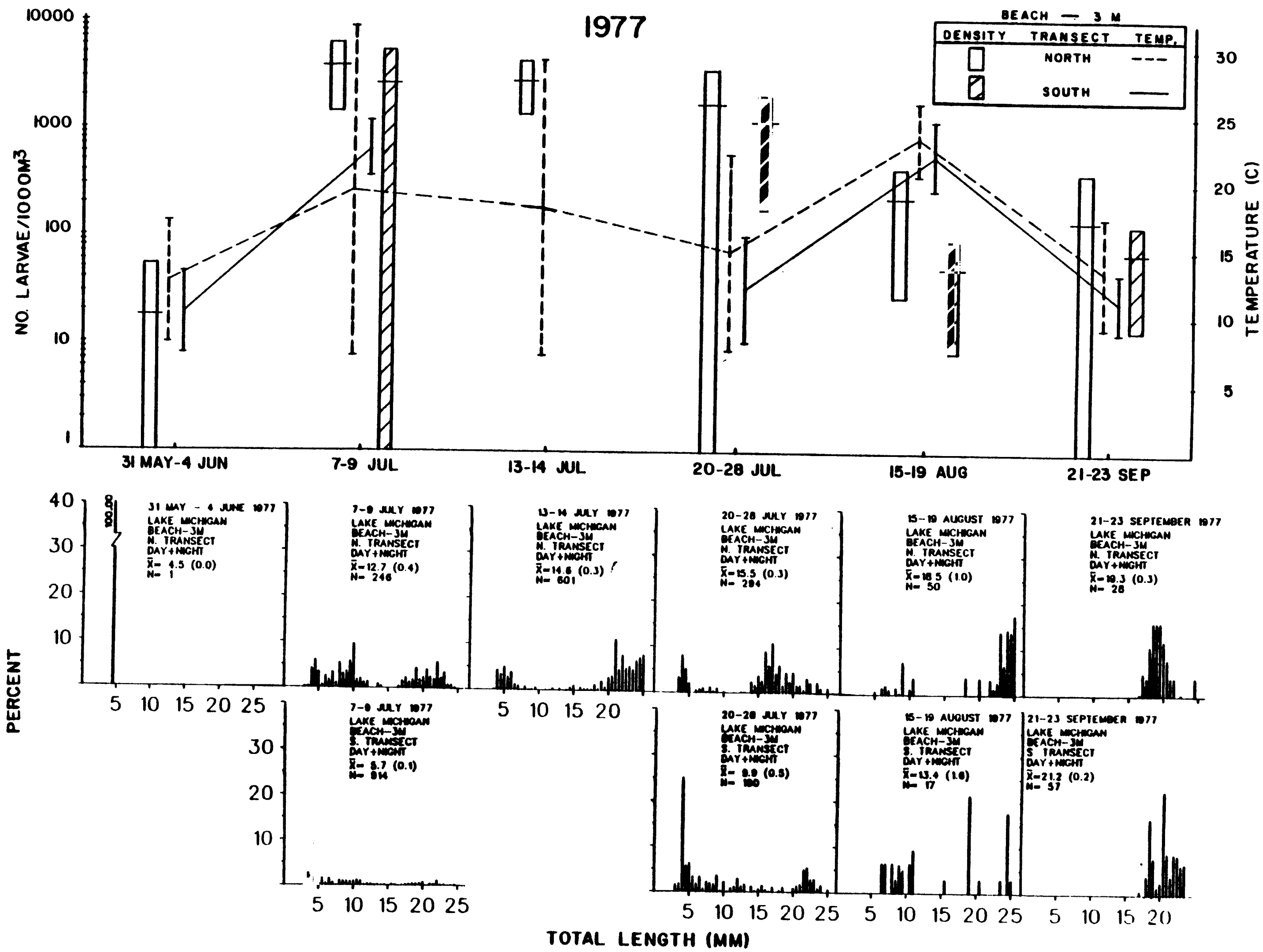


Fig. 8. Density (no./1000 M^3 plotted on log scale) of larval alewives collected during June to September 1977 at beach - 3 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = Number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

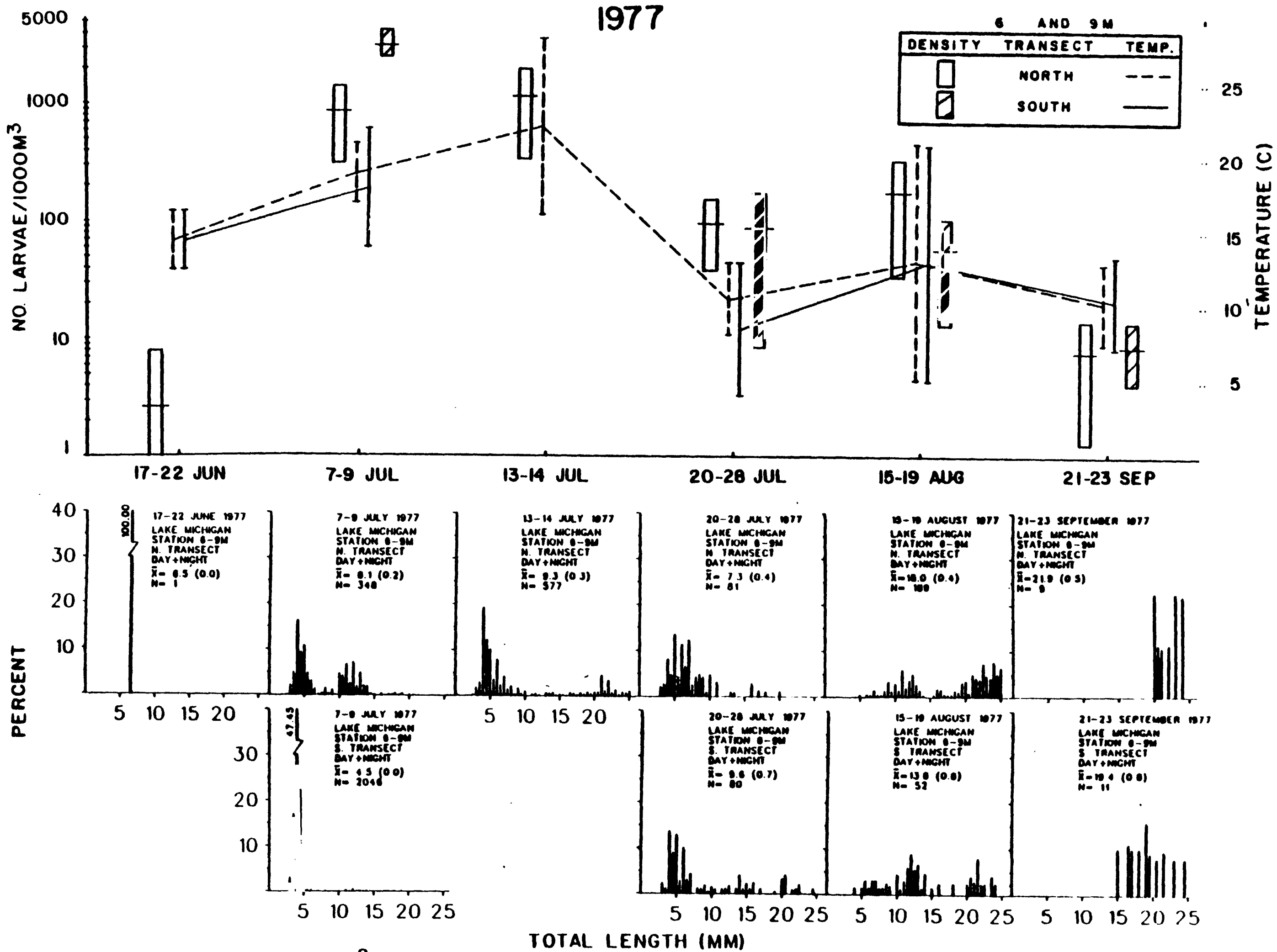


Fig. 9 . Density (no./1000 M^3 plotted on log scale) of larval alewives collected during June to September 1977 at 6 and 9 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

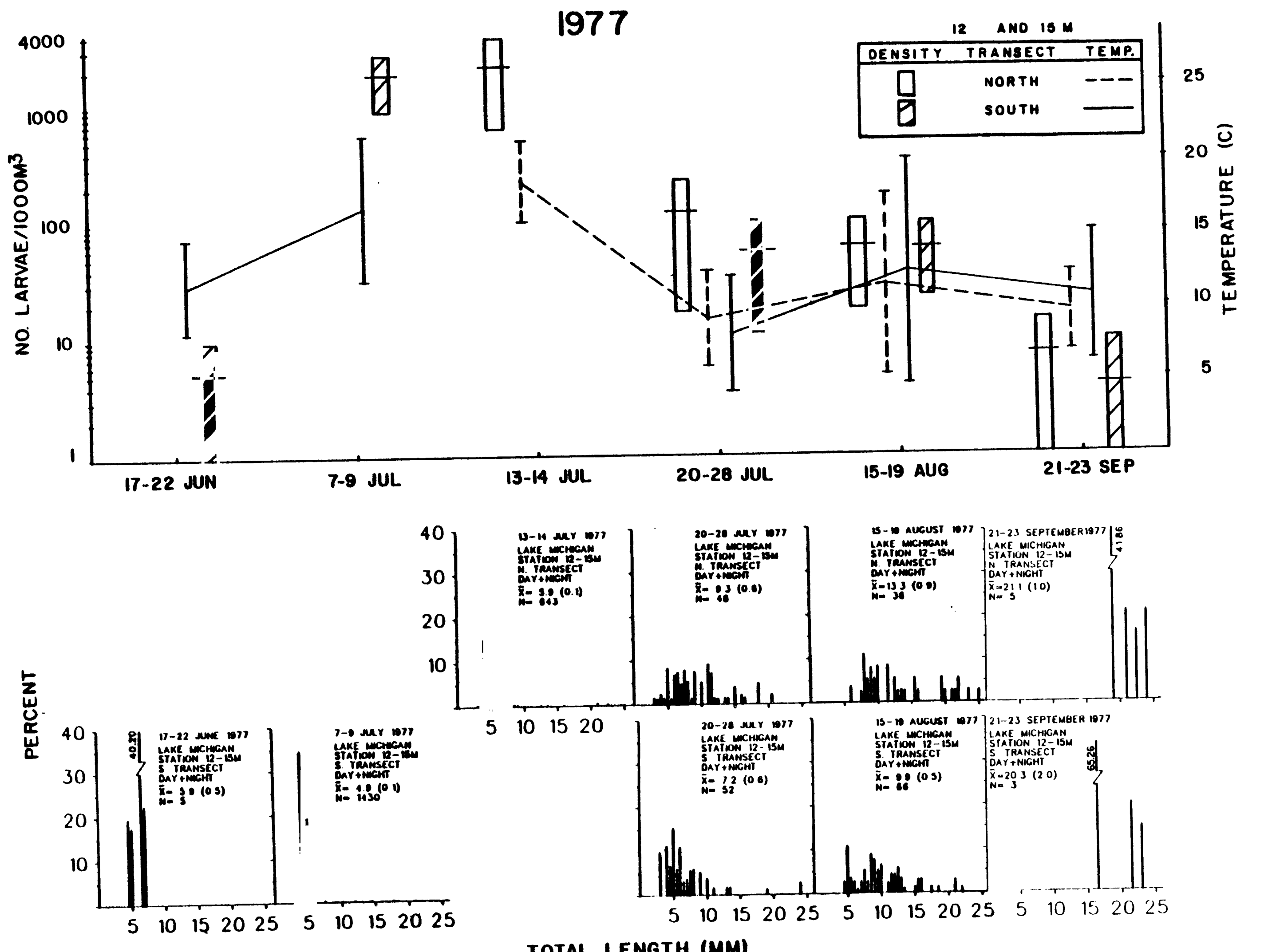


Fig. 10. Density (no./1000 M^3 plotted on log scale) of larval alewives collected during June to September 1977 at 12 and 15 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

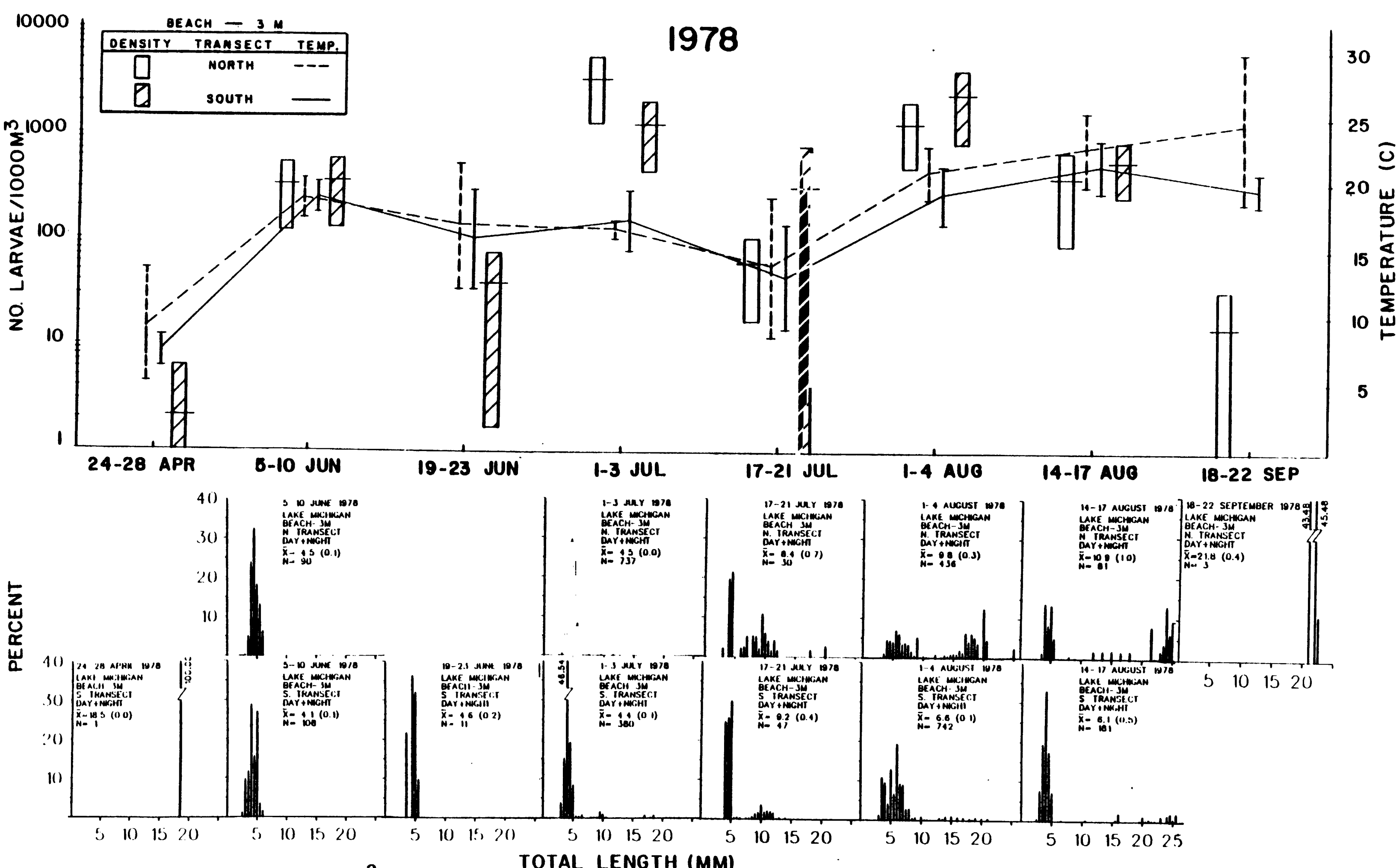


Fig. 11. Density (no./1000 M^3 plotted on log scale) of larval alewives collected during April to September 1978 at beach - 3 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

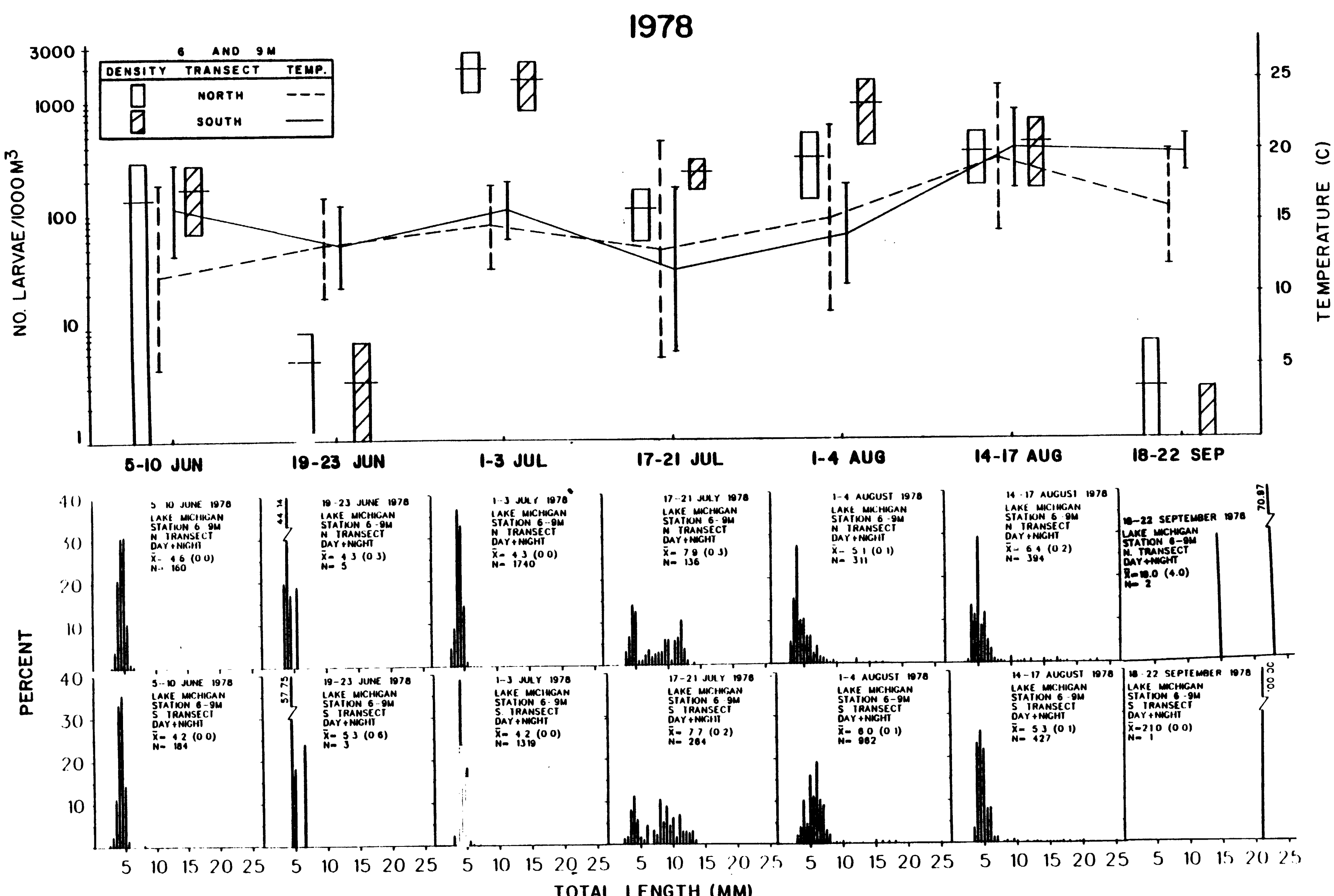


Fig. 12. Density (no./1000 M^3 plotted on log scale) of larval alewives collected during April to September 1978 at 6 and 9 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

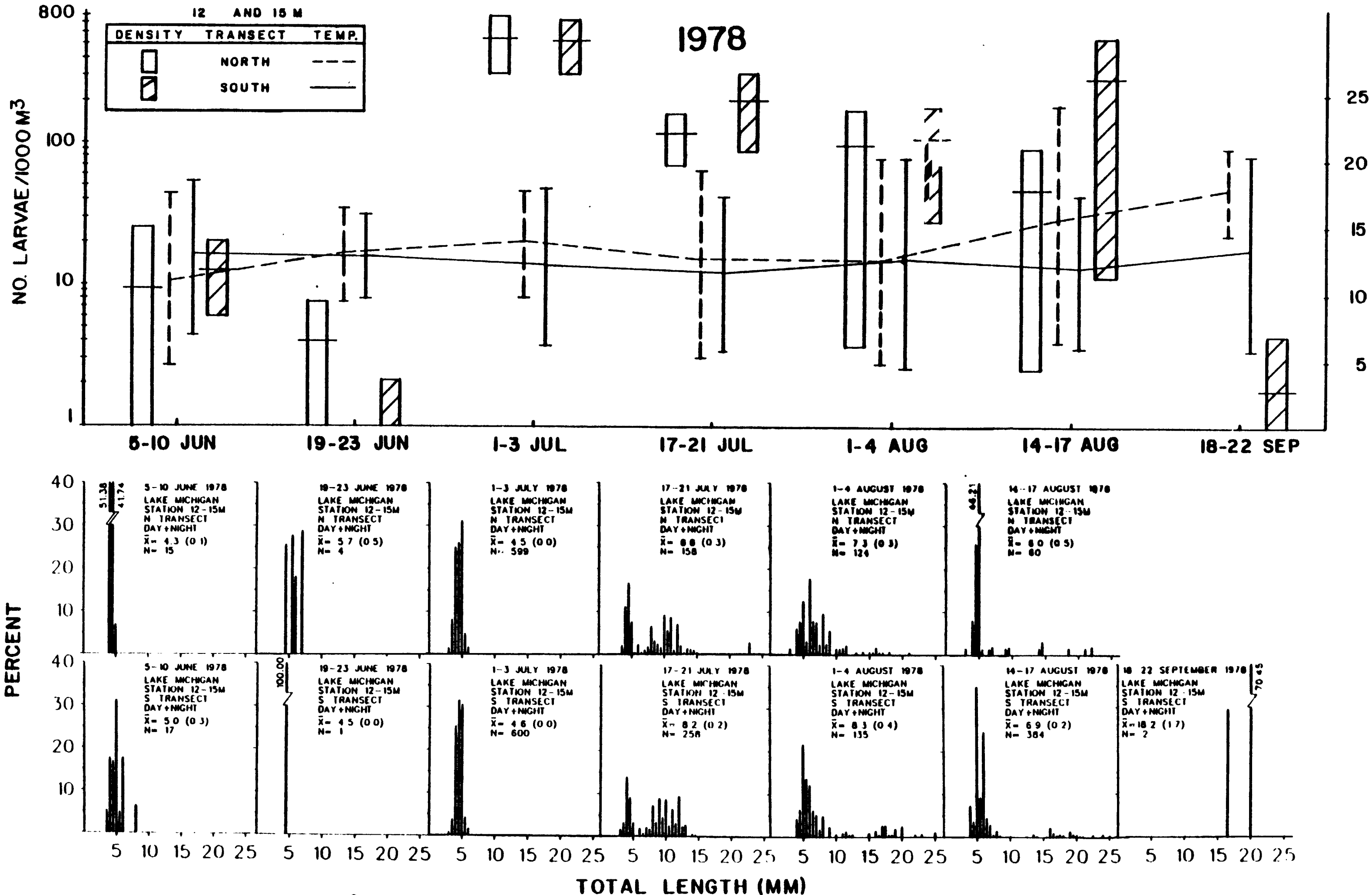


Fig. 13. Density (no./1000 M^3 plotted on log scale) of larval alewives collected during April to September 1978 at 12 and 15 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

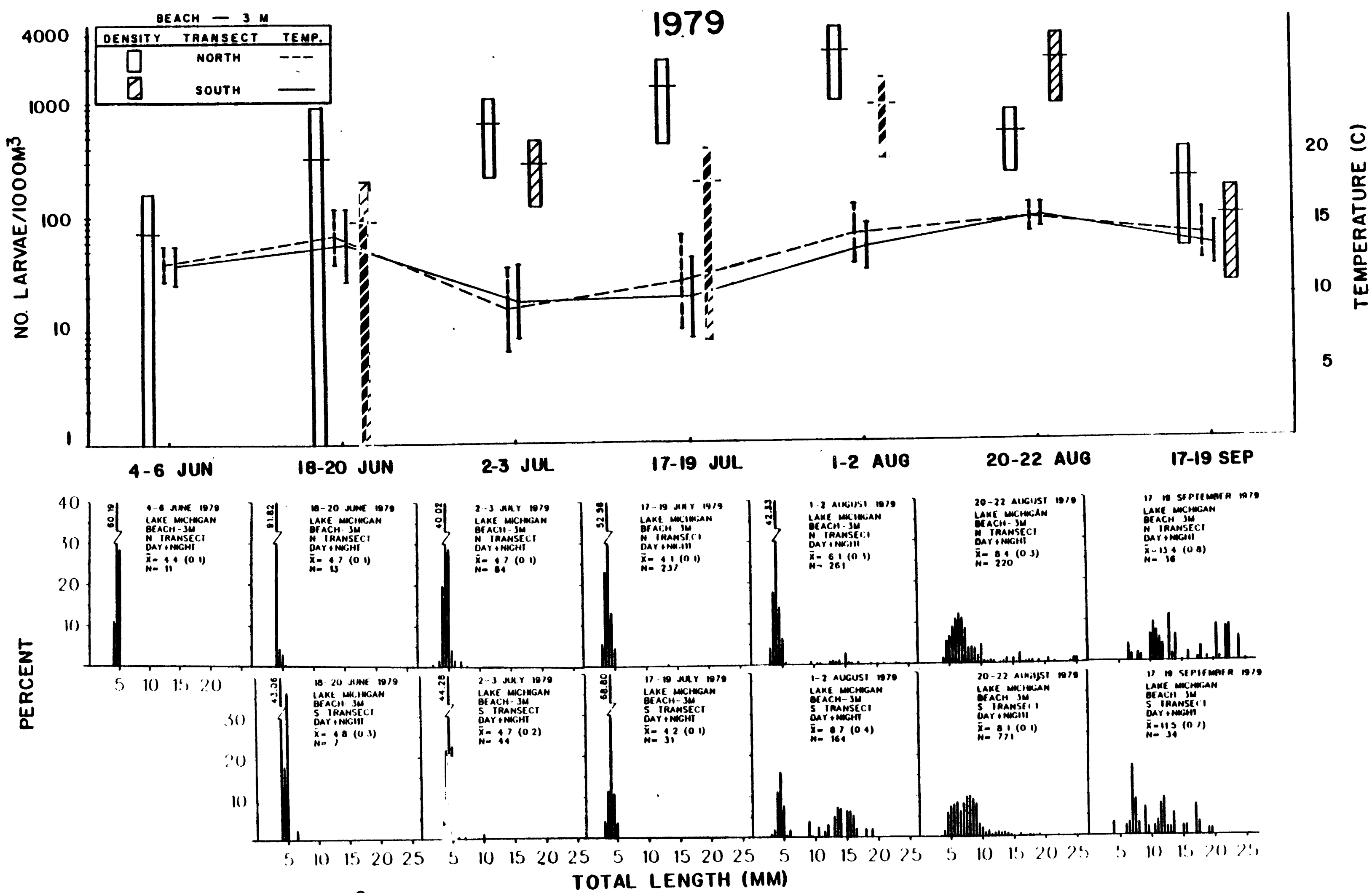


Fig. 14. Density (no./1000 M^3 plotted on log scale) of larval alewives collected during April to September 1979 at beach - 3 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

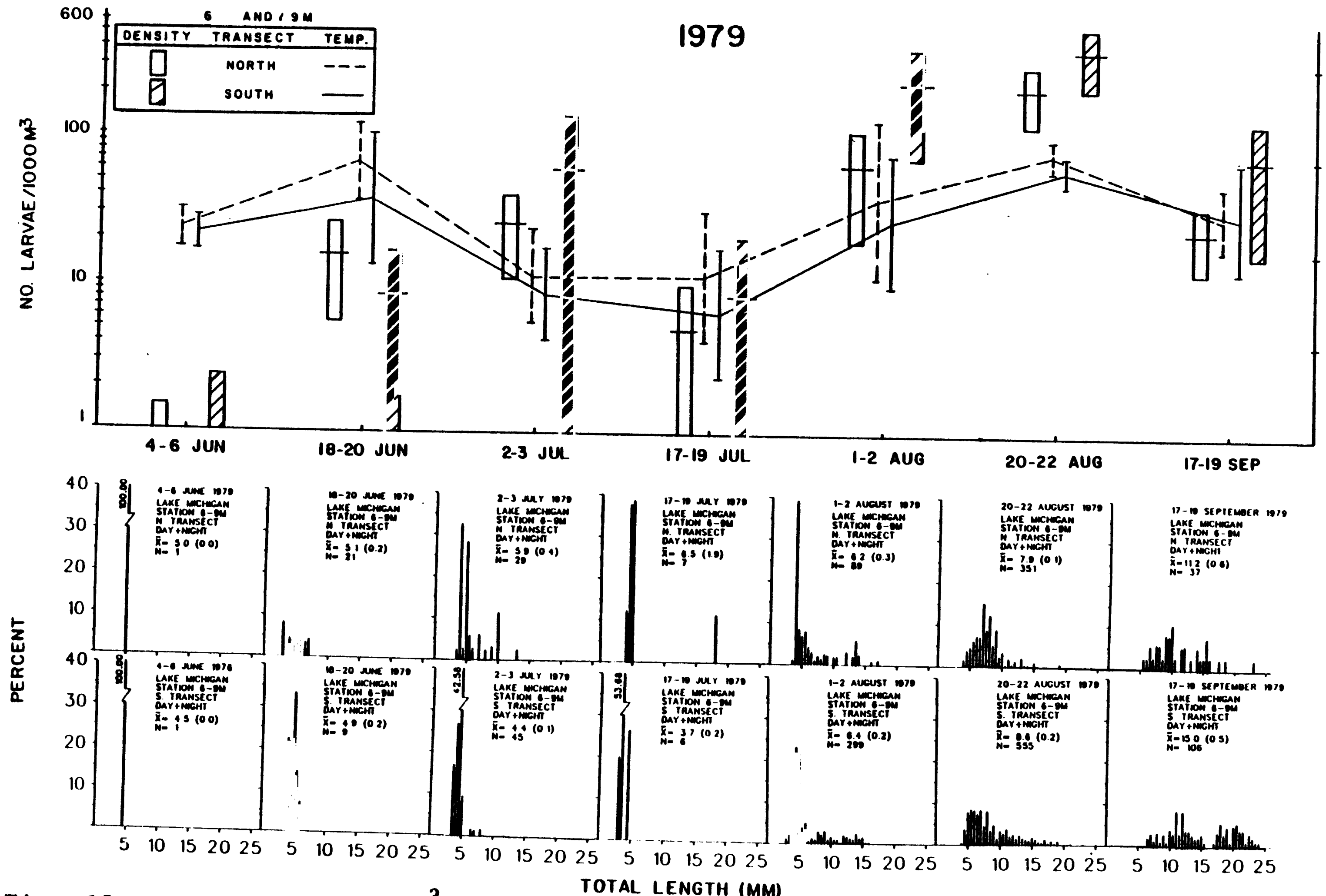


Fig. 15. Density (no./1000 M^3 plotted on log scale) of larval alewives collected during April to September 1979 at 6 and 9 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

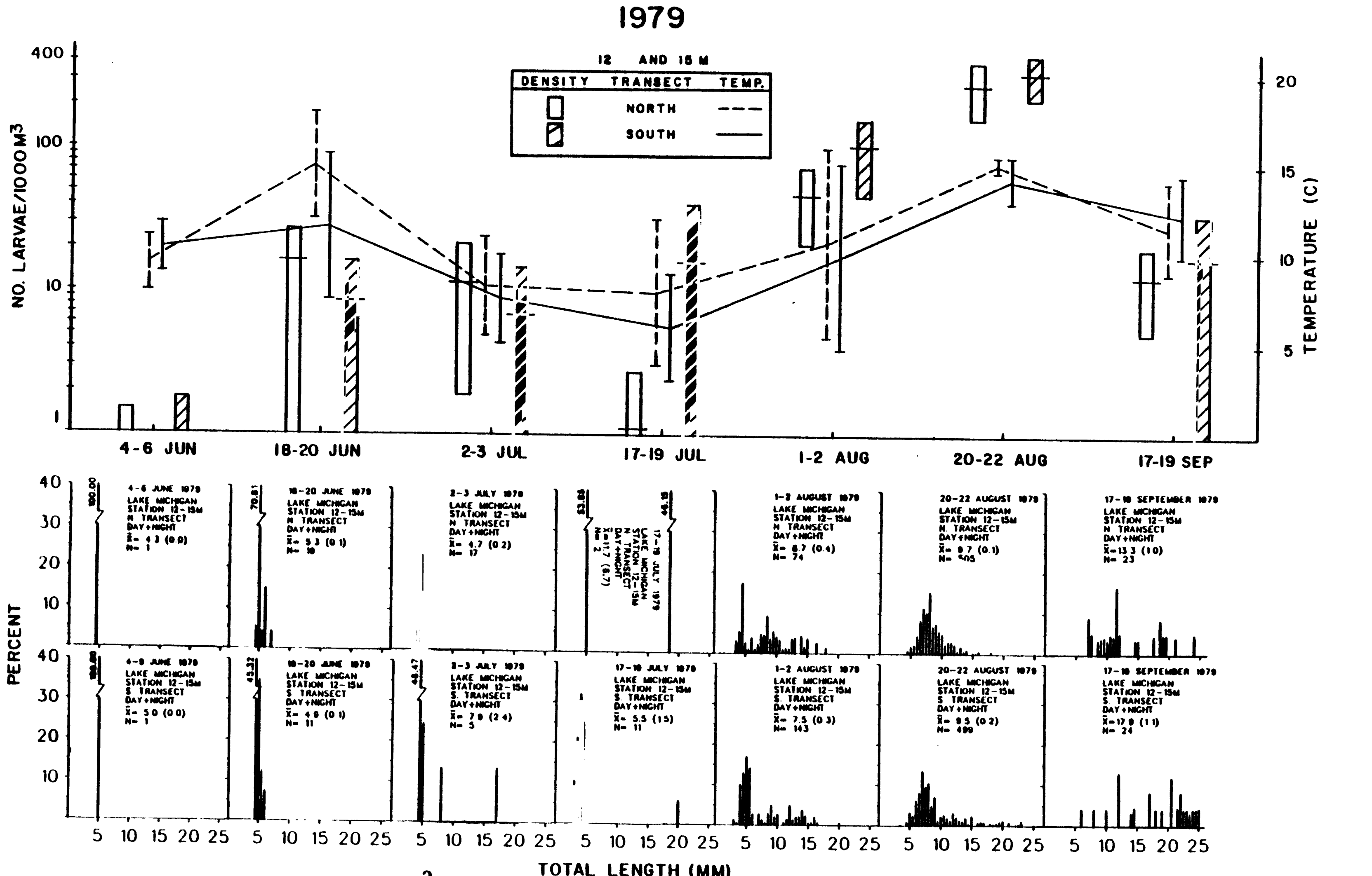


Fig. 16. Density (no./1000 M^3 plotted on log scale) of larval alewives collected during April to September 1979 at 12 and 15 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

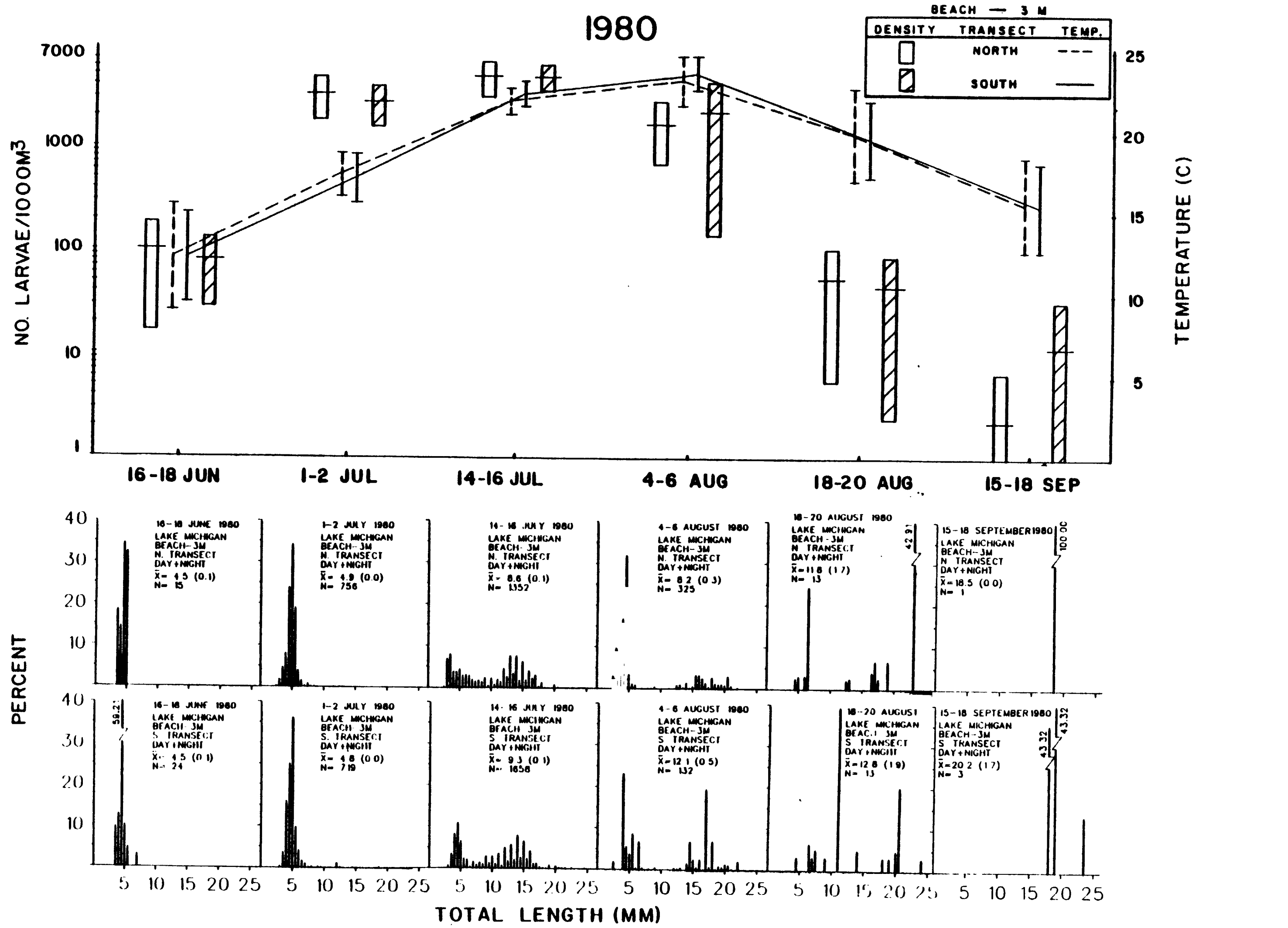


Fig. 17. Density (no./1000 M^3 plotted on log scale) of larval alewives collected during April to September 1980 at beach - 3 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

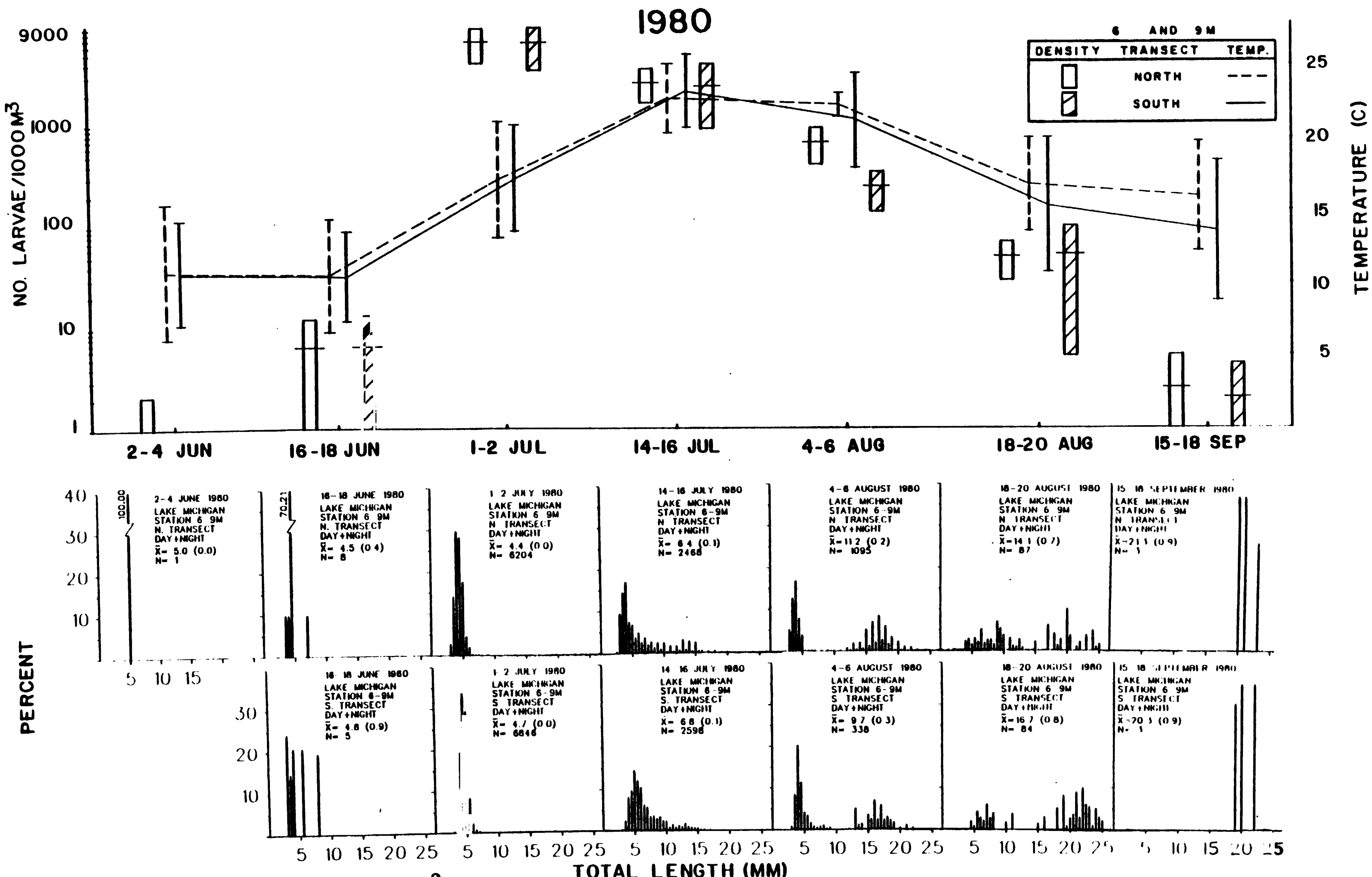


Fig. 18. Density (no./1000 M^3 plotted on log scale) of larval alewives collected during April to September 1980 at 6 and 9 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

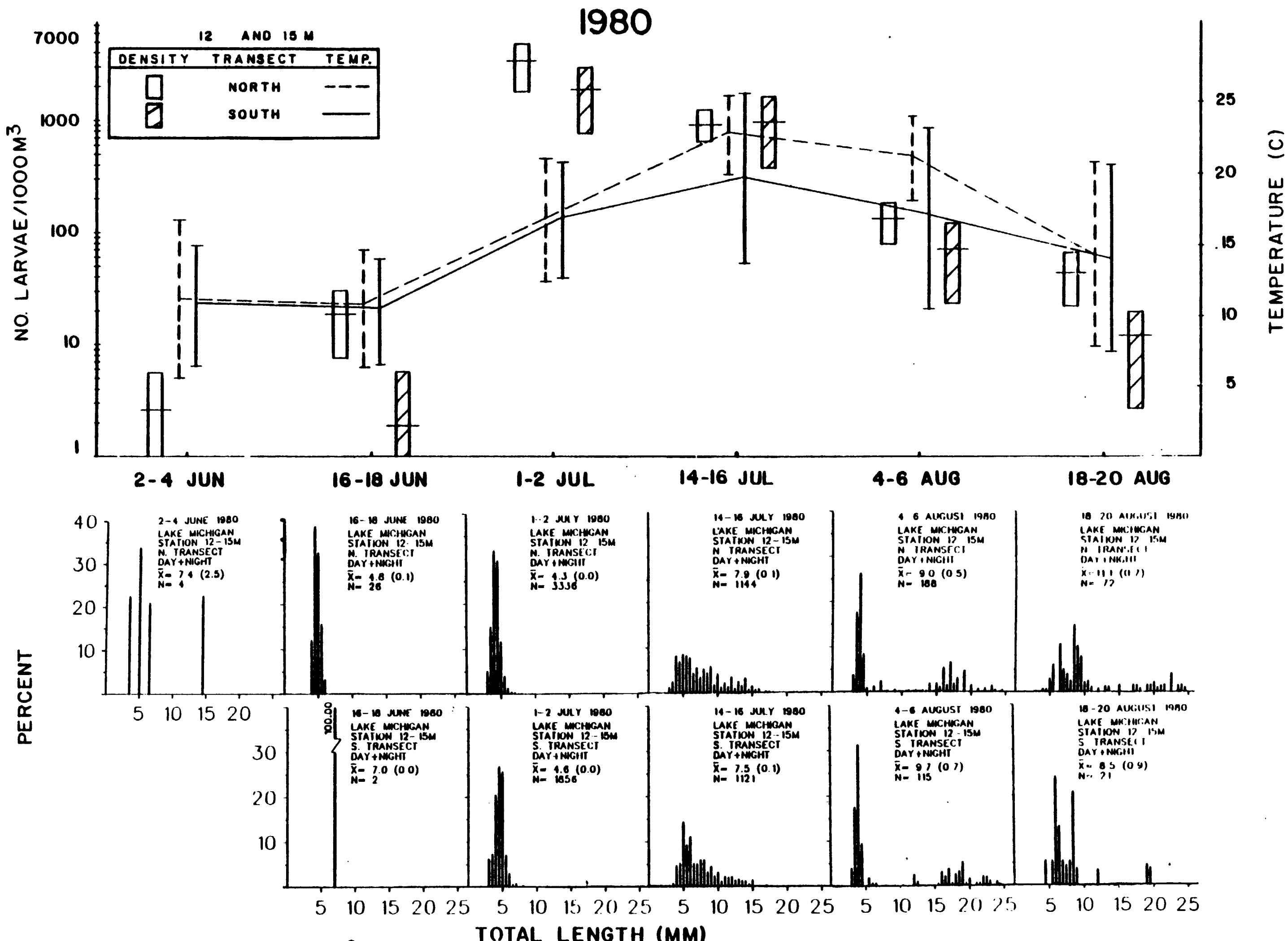
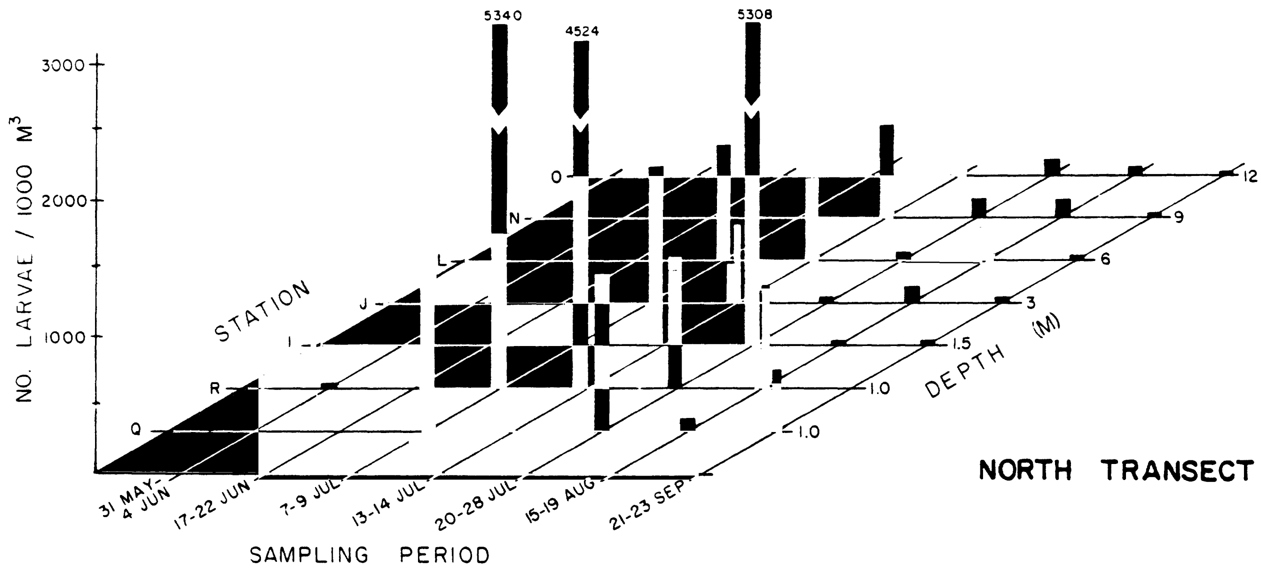


Fig. 19. Density (no./1000 M^3 plotted on log scale) of larval alewives collected during April to September 1980 at 12 and 15 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

1977



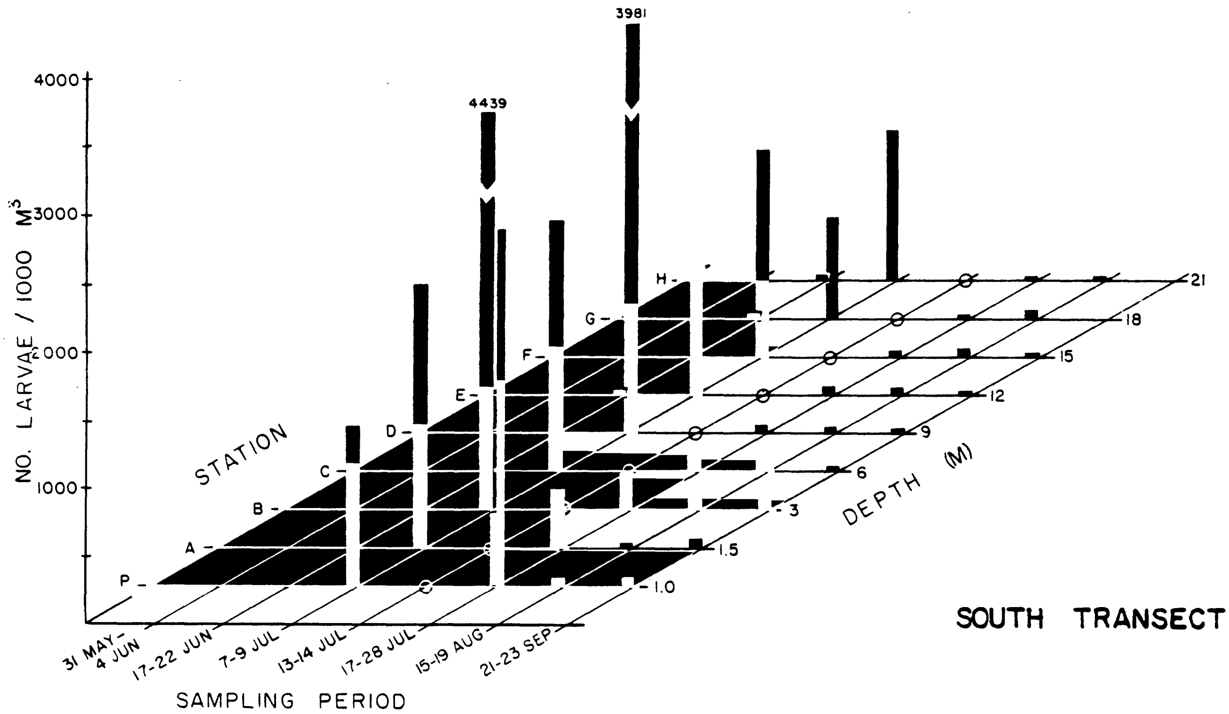
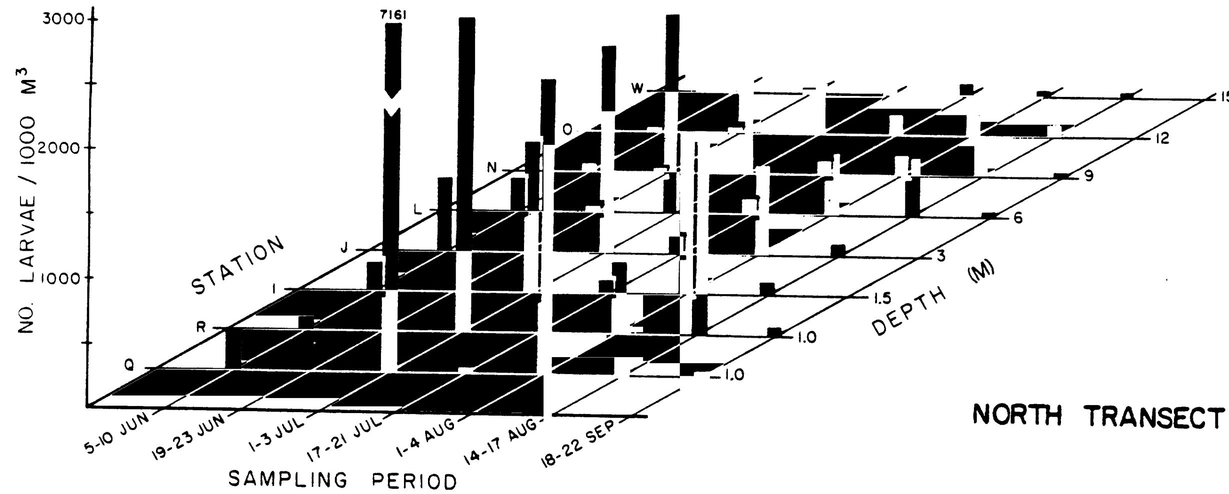


Fig. 20. Mean density (no./1000 m^3) of larval alewives for north and south transect stations in Lake Michigan near the J. H. Campbell Plant, 1977 to 1980. Mean densities were calculated by averaging densities over all gear (plankton nets and sleds), strata and diel periods (day and night) sampled. O = no sampling performed.

1978



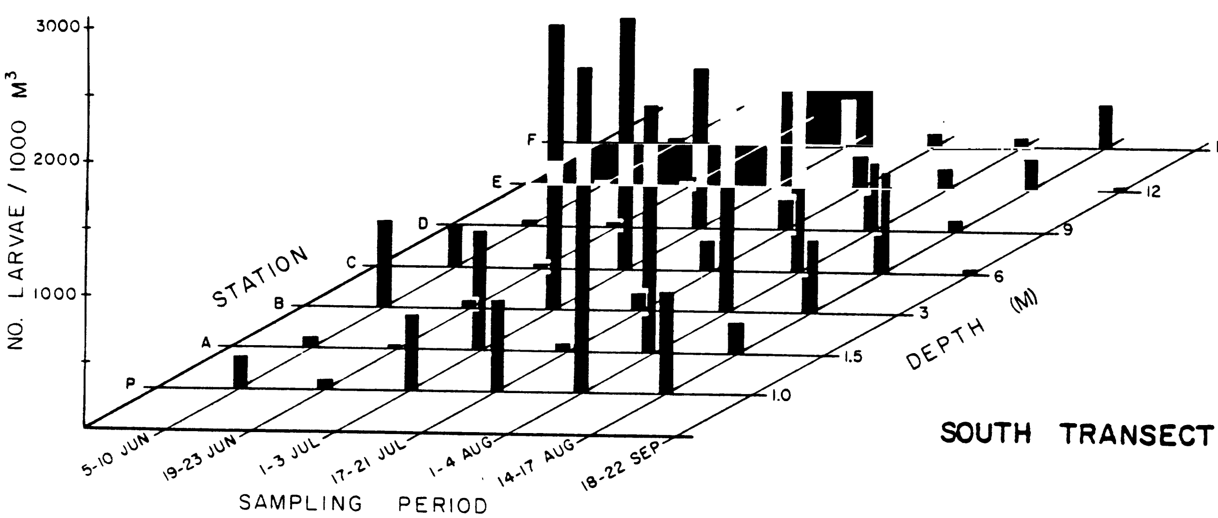
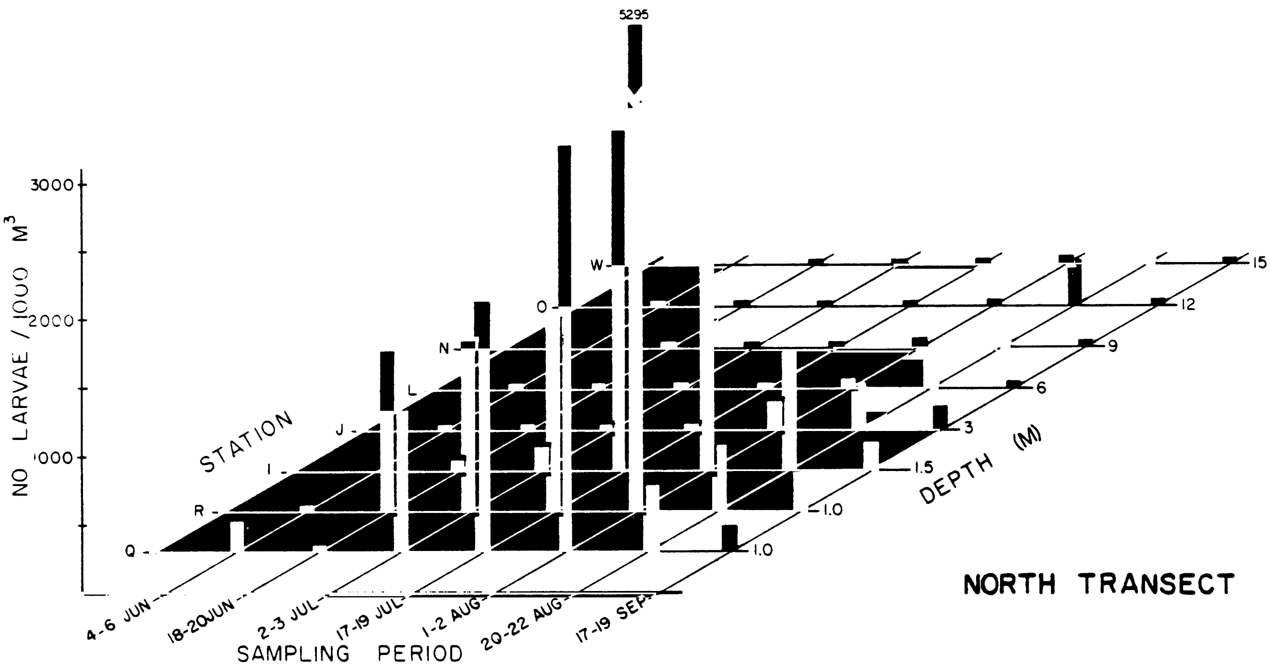
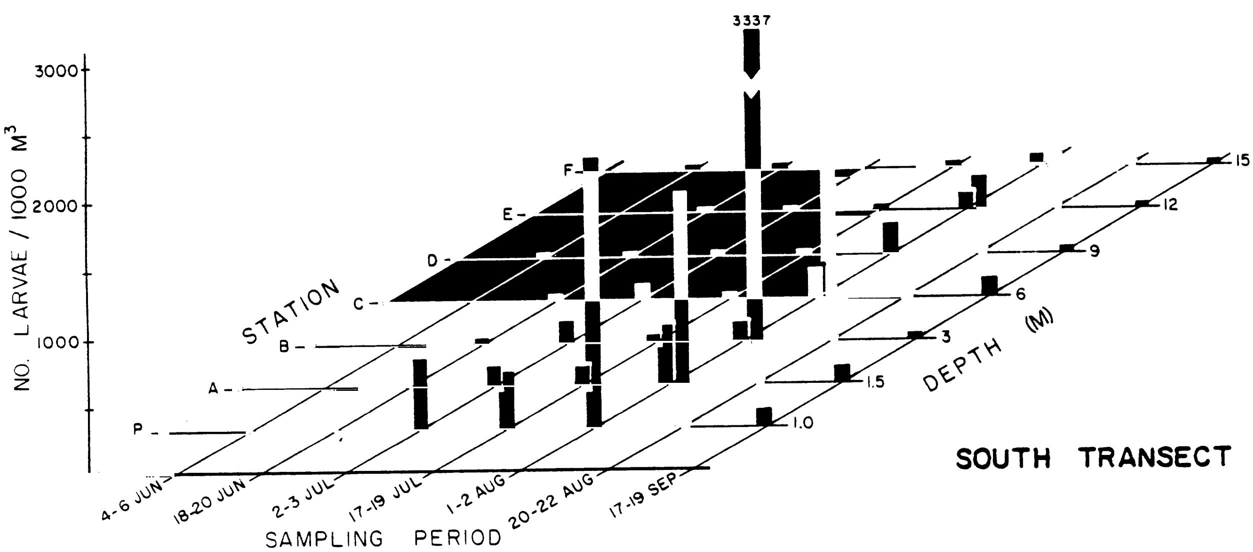


Fig. 20. Continued.

1979





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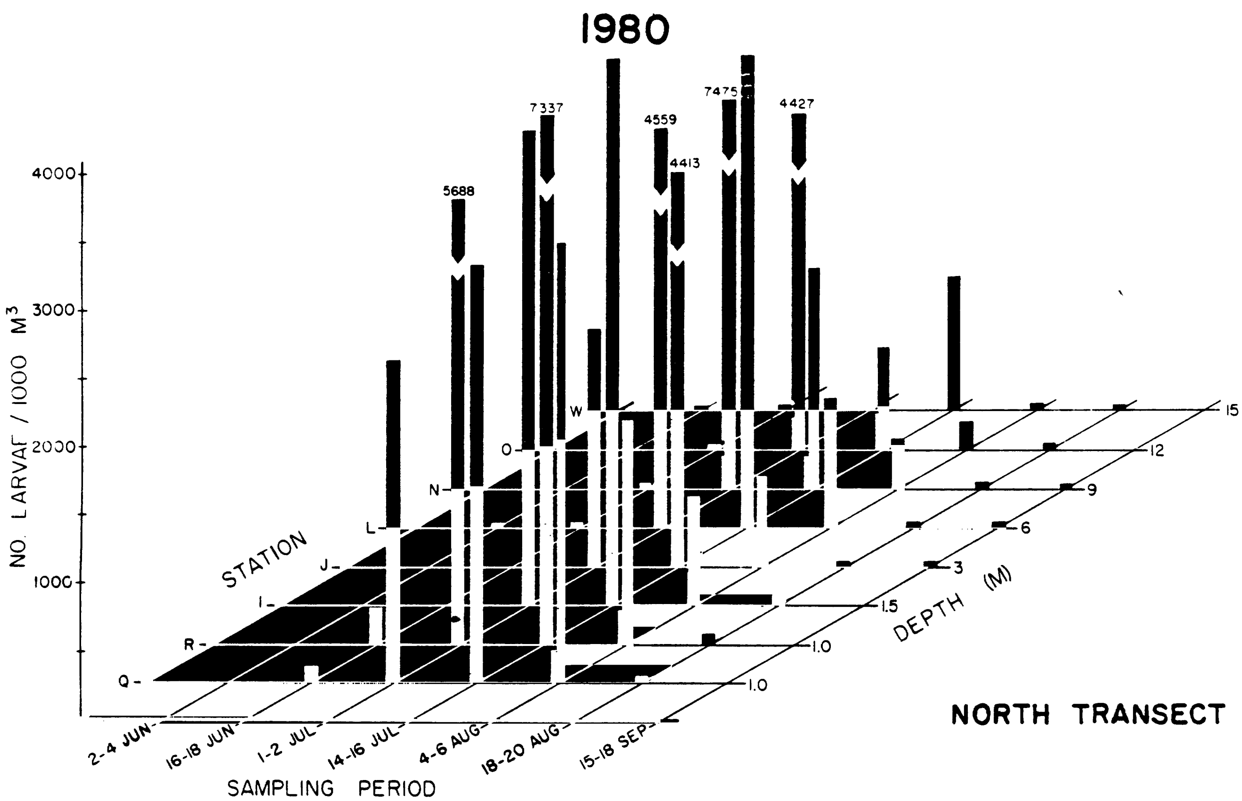


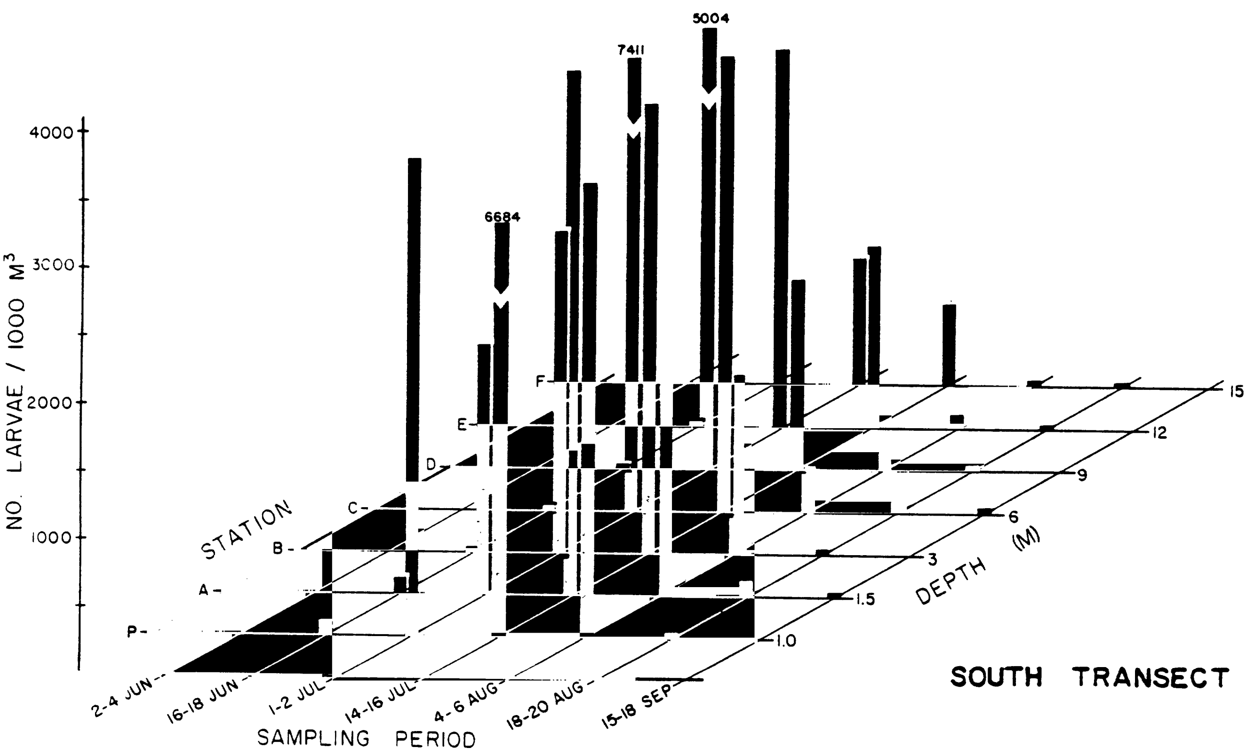


Fig. 20. Continued.

Early July--For all years studied, the first sampling period in July marked the first major occurrence of larval alewives near Port Sheldon (Figs. 8-19). With the exception of early July 1979, mean densities at the beach to 3 m and 6- and 9-m stations ranged from 1000 to over 6000 larvae/1000 m^3. During early July 1979, a cold-water upwelling depressed water temperatures below those conducive to alewife spawning, and thus mean densities at the beach to 3-m stations did not exceed 660 larvae/1000 m^3, and no mean densities exceeding 70 larvae/1000 m^3 were observed at the 6- to 9-m and 12- to 15-m stations.

There are at least three possible mechanisms by which cold-water upwellings could affect the abundance of alewife larvae in the study area. The first is the effect of cold-water upwelling on adults expected to spawn in the area. Our studies indicate that many adult alewives move from the nearshore zone affected by an upwelling (see RESULTS AND DISCUSSION, Alewife, Adults, Seasonal distribution). This movement from the area by the spawning stock, as well as the retarding effect cold water would have on the spawning stock that remained in the area, would dramatically affect egg deposition and hence recruitment of newly hatched larvae. Newly hatched individuals comprised the majority of larvae in our early July samples in all years. Another effect a cold-water upwelling may have on recruitment of newly hatched larvae is direct mortality or decreased survival of alewife eggs deposited just prior to the upwelling. Edsall (1970) observed that the development of a functional jaw in larval alewives did not occur at water temperatures less than 10 C. Water temperatures below 10 C are frequently observed during upwellings. The third mechanism by which upwellings could affect abundance of alewife larvae in the study area is by transporting newly hatched passive larvae offshore with surface currents. The fate of larvae transported from the nearshore zone to the offshore zone is uncertain. Since the alewife has adapted to spawn in the nearshore zone, it is probably most advantageous for larvae to use the nearshore zone as a nursery. Thus factors which would distribute the larvae offshore probably negatively affect their survival. It is likely that the aforementioned mechanisms exert differential effects on the abundance of larval alewives which are dependent on the extent of the upwelling.

There was a general tendency over the 4-yr study for larval alewives to be more concentrated at depths of 9 m or less. This tendency was more pronounced during times of upwelling when nearshore stations had relatively higher water temperatures.

Early July sampling during 1977-1980 confirmed that the first substantial alewife spawning activity usually took place in late June to early July. There is also a clear indication that upwellings have a depressing effect on spawning and hatching.

During 1977 when the Units 1 and 2 discharge canal opened at the shoreline of Lake Michigan substantial spawning occurred in the discharge canal during early June. Early July 1977 length-frequency histograms from the north and south transects beach to 9-m stations were compared (Figs. 8-10). They showed that a considerably higher proportion of larvae captured at the

north transect stations exceeded 10 mm total length when compared with the south transect catch. We believe that early spawning in the onshore warm-water discharge in Lake Michigan was responsible for the observed differences.

Late July--The effect of cold-water upwelling was most clearly observed during late July sampling. For 1977-1979, deflections in the warming trends (Figs. 8-16) in late July indicated an upwelling either during sampling or just prior to it. The result of the upwellings during late July 1977 and 1978 was reduced mean densities at all station groupings, compared with earlier July densities of these same years (Figs. 8-13). Since an upwelling was present during both July 1979 sampling periods, low mean larval alewife densities were observed for that entire month (Figs. 14-16). Presence of upwellings generally resulted in a more nearshore distribution of larvae, as can be seen in late July 1977 and 1979 (Figs. 8-19), which is probably related to increased spawning and hatching in warmer nearshore water. During late July 1978 sampling, the effect of an upwelling, which occurred just prior to our collections, was diminishing and a more general distribution of larvae to 15 m occurred (Figs. 11-13).

There was a striking difference between late July sampling in 1977-1979 and 1980. During the 1980 period, no interruption in the summer warming trend of the inshore zone was observed, and the intensive spawning and hatching activity, observed in early July, continued. Mean densities at nearshore (beach to 3 m) stations in late July 1980 were clearly higher than offshore stations, exceeding 4000 larvae/1000 m^3 (Figs. 17-19).

Thus it appears that if a warming trend continues uninterrupted throughout July in the inshore zone, intensive hatching, resulting in mean densities often exceeding 2000 larvae/1000 m^3, might be expected to depths of 15 m. If a warming trend is interrupted by an upwelling, a diminishing effect on spawning and hatching might be expected, resulting in mean densities well below 2000 larvae/1000 m^3. The extent of this attenuating effect of upwellings on larval alewife abundance is dependent on upwelling intensity and duration.

Early August--Resumption of a summer warming trend in early August 1978 and 1979 resulted in substantially higher mean densities of larval alewives compared with late July in these years (Figs. 11-16). Continued warming of inshore water during early August 1980 resulted in mean densities of alewife larvae which were comparable to levels in early August 1978 and 1979 (Figs. 17-19); however, these mean densities were much lower than densities measured during late July 1980. Lower densities of alewife larvae in early August 1980 compared with late July 1980 suggest a tapering off of an alewife spawning peak which occurred in early to mid-July. Thus it appears that the upwelling temporarily delayed spawning and hatching. A resumption of the inshore summer warming trend resulted in increased spawning and hatching. During years when there were no significant upwellings and the warming trend proceeded uninterrupted, a more defined spawning peak would be expected in July, and a tapering off of the peak would be expected in August, as was observed in 1980.

Distribution of larval alewives for all 3 yr in which early August samples were taken (1978-1980) showed similar trends. Highest mean densities were at beach and 3-m stations, with successive declines at 6- to 9-m and 12- to 15-m stations. It is this distributional trend which is most common, except when the major hatching peak occurs, which can occur in June-August. During those peak hatching periods the distribution of larval alewife was more widespread out to depths of 15 m.

Examination of early August length-frequency data comparing north with south transects over the 3 yr revealed few differences. During early August 1978, a substantially higher proportion of larvae captured within the nearshore zone (beach and 3 m) at the north transect exceeded 10 mm while those within the similar south transect area were less than 10 mm (Figs. 11-13). A reverse of this trend was observed during early August 1979 and 1980 (Figs. 14-19); thus we feel that length-frequency differences observed between transects at these times were attributable to natural variability rather than plant effects.

Late August--During most years sampled, hatching tapered off in late August. This decline was most evident during 1980 when, as previously noted, the lack of substantial upwellings resulted in a more defined hatching peak in July. Mean densities at any of the station combinations during late August 1980 did not exceed 55 larvae/1000 m^3, while late August sampling during 1977 and 1978 showed consistently higher mean densities (60-541 larvae/1000 m^3) (Figs. 8-19). During late August 1979, even higher densities (up to 2150 larvae/1000 m^3) were observed. These data support the contention that upwellings cause an apportioning of spawning over a longer period of time, resulting in less defined peaks in abundance. Duration of major spawning effort is determined by duration of the upwellings. During 1979 when there was an extended upwelling through July, there was still substantial spawning occurring in late August. During 1978 and 1979, upwellings were present only in mid- and late July, resulting in substantial spawning into early August. For these 2 years through early July the primary spawning peak was dictated by physical factors.

During all study years there was a general tendency in late August for larvae to be more concentrated at depths of 9 m or less when compared with 12- and 15-m stations (Figs. 8-19). Length-frequency data indicated that during most years a substantial portion of the larvae captured in late August were hatched within 2 wk or less prior to sampling (Figs. 8-19).

September--With initiation of cooling in Lake Michigan in September, alewife spawning generally ceases. Substantial decreases in mean larval alewife densities were observed in September of all years when compared with late August (Figs. 8-19). These decreased densities of larval alewives in September reflect the lack of recruitment of newly hatched larvae as well as net avoidance by larger larvae which would be expected at this time.

Length-frequency histograms from September 1979 stand out from those of the other years (Figs. 14-16). During 1977, 1978 and 1980 all alewife larvae captured in September were 15 mm or longer (Figs. 8-19). In September 1979,

in excess of 50% of the larvae captured were less than 15 mm, indicating that they probably were spawned and hatched in early September. This abnormal extension of spawning in September 1979 was probably due to the extensive upwelling which occurred in July 1979. The effect this delayed spawning has on survival of larvae hatched so late in the growing season is unknown. We believe these larvae experience higher winter mortality than larvae hatched earlier in the season.

Young-of-the-Year--

As larval alewives grow during summer months, they become increasingly susceptible to capture by seines and trawls. It is at this point of susceptibility that we refer to them as young-of-the-year (YOY). YOY are an extremely important age-group of fish since they have survived the period of highest mortality. Since it is assumed that this age-group would have the highest probability of impingement on the 9.5-mm wedge-wire intake screens, a documentation of their preoperational distribution relative to the intakes was essential.

Seasonal distribution--Generally, the first substantial catch of YOY alewives in any year occurred in August (Fig. 21). The exception to this trend was observed in July 1977 when over 5000 YOY were captured in seine hauls at beach stations in Lake Michigan (Fig. 21). Although this might appear to indicate that spawning had occurred earlier in Lake Michigan during this year, larval fish data from Lake Michigan stations do not support this hypothesis (see RESULTS AND DISCUSSION, Alewife, Larvae, Seasonal distribution). The most notable correlation which could explain the early occurrence of YOY alewives in Lake Michigan in 1977 was found by examining larval fish data from adjacent Pigeon Lake for 1977-1979 (Jude et al. 1978, 1979a, 1980). Over the 3-yr study period, the most intensive early June spawning of alewives was observed in 1977 when densities of alewife larvae were high (near 2000 larvae/1000 m^3) at two of the three beach sampling stations in Pigeon Lake. It was thus strongly indicated that Pigeon Lake was used as an early June spawning area by many adult alewives. It is possible that these larvae used the area of Pigeon Lake as a nursery area and moved out into Lake Michigan in July in 1977. Another possible origin of the YOY caught in July 1977 may have been the discharge canal which in that year opened unobstructed at the shoreline of Lake Michigan. We believe that early June spawning took place there by either early inshore migrating alewives from Lake Michigan or a resident population of alewives from the canal itself. During early June 1978 and 1979 no larval alewives were reported at beach stations in Pigeon Lake (Jude et al. 1979a, 1980) indicating that during these years very little early June alewife spawning occurred there. In contrast to July 1977, only one YOY was caught at adjacent Lake Michigan beach stations during July 1979 and none were caught in July 1978.

Although July data suggest that YOY alewives remain in the nearshore zone, larval fish data (see RESULTS AND DISCUSSION, Alewife, Larvae, Seasonal distribution) indicate that some larvae which have overlapping size ranges (15-25 mm) with those classified as YOY, were distributed to the 15-m depth contour in July of all years.

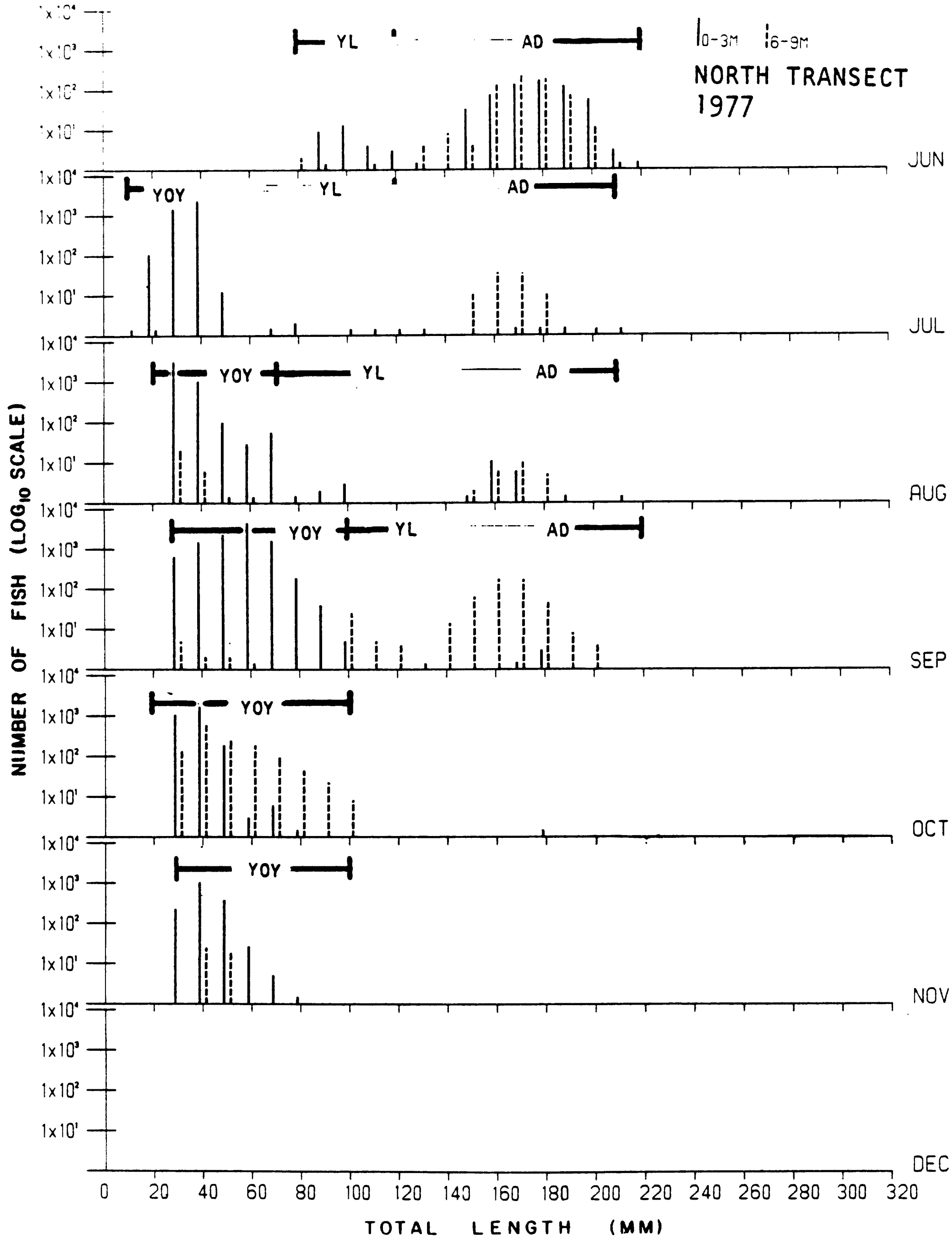
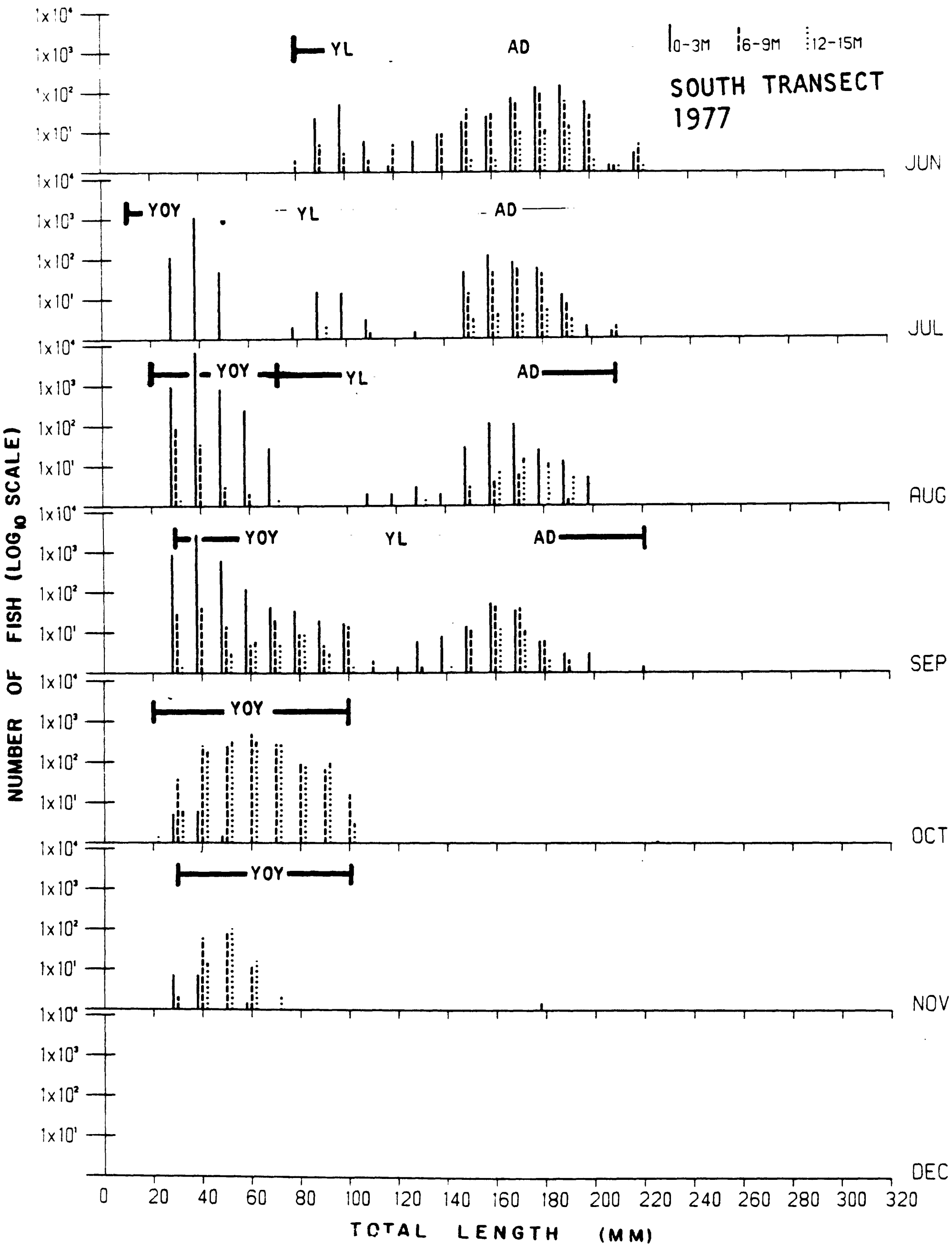


Fig. 21. Length-frequency histograms for alewives collected during June - December 1977 and April - December 1978-1980 at north and south transects. Stations were combined into two groups for the north transect: beach and 3 m; 6 and 9 m and into three groups for the south transect: beach, 1.5 and 3 m; 6 and 9 m; and 12 and 15 m. Diel periods and gear types were pooled. YOY = Young-of-the-year; YL = Yearling; AD = Adult.



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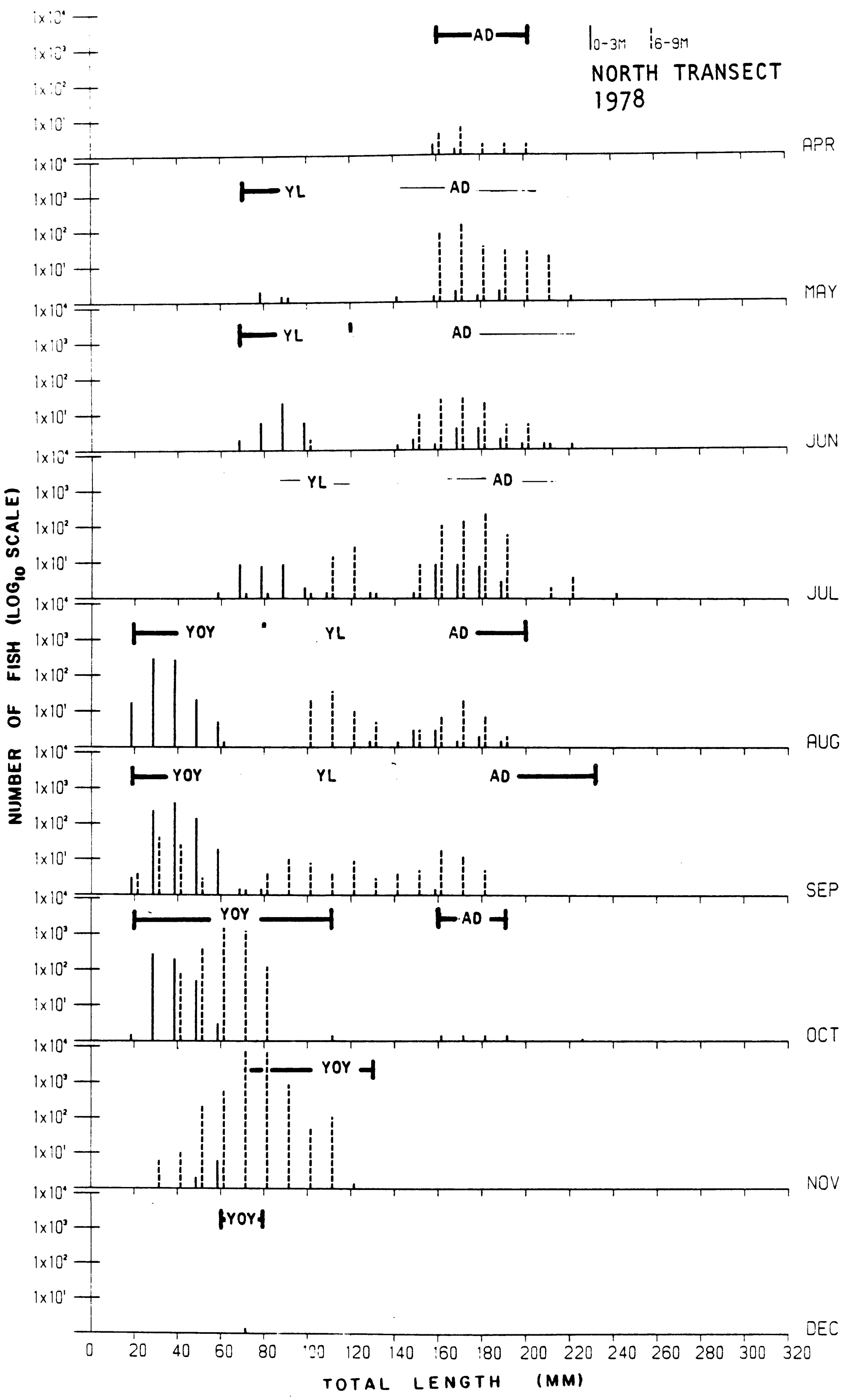

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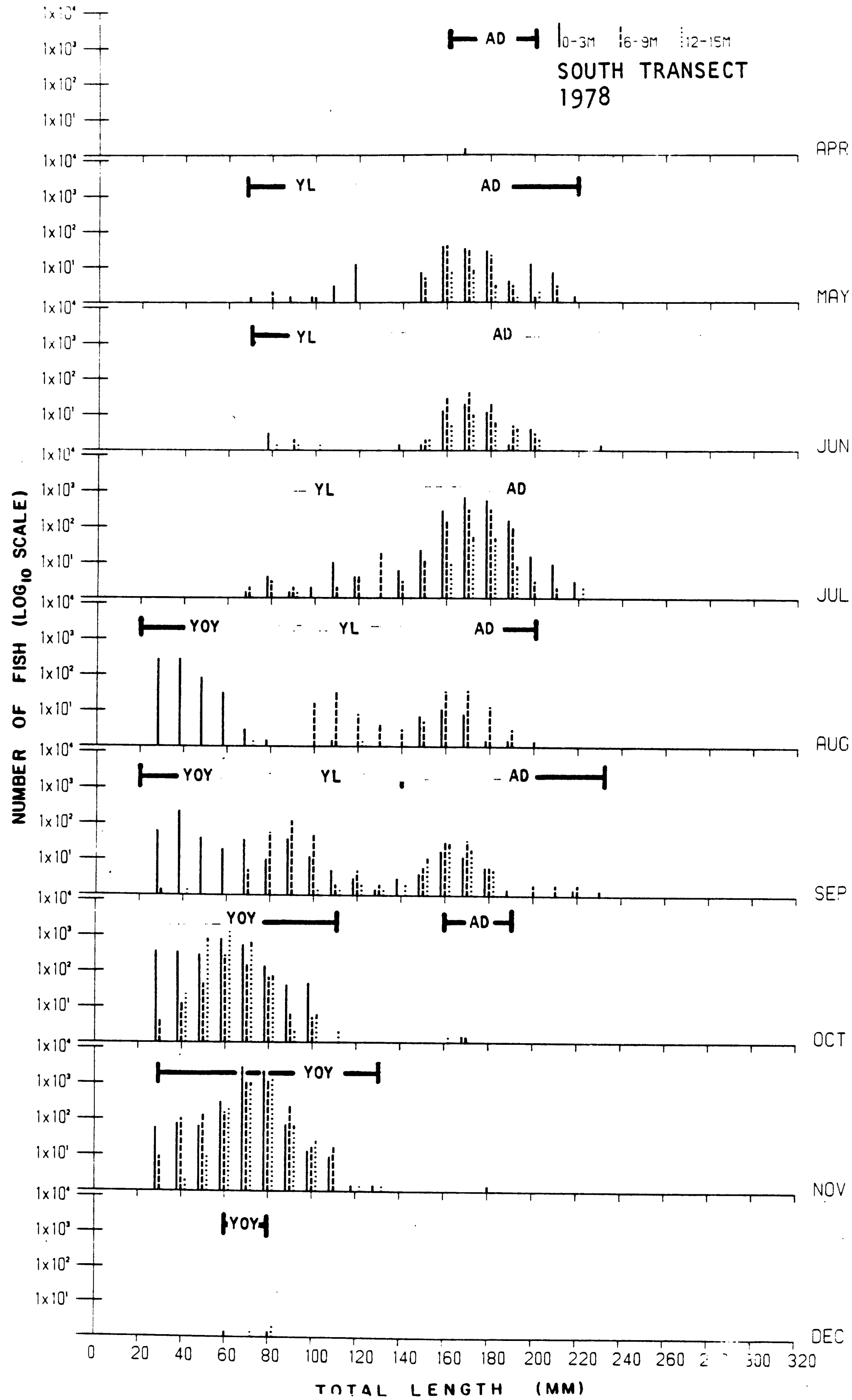

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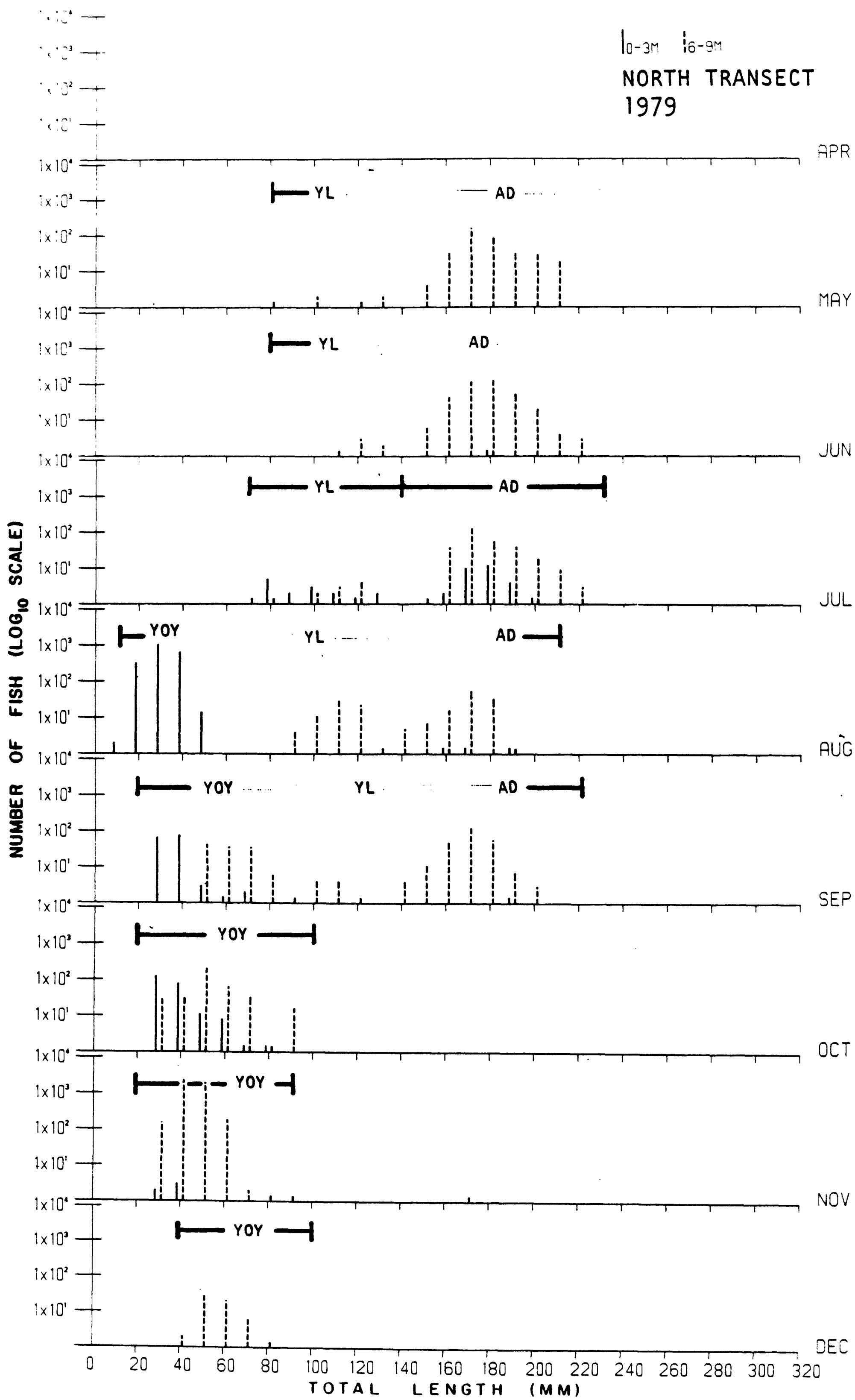

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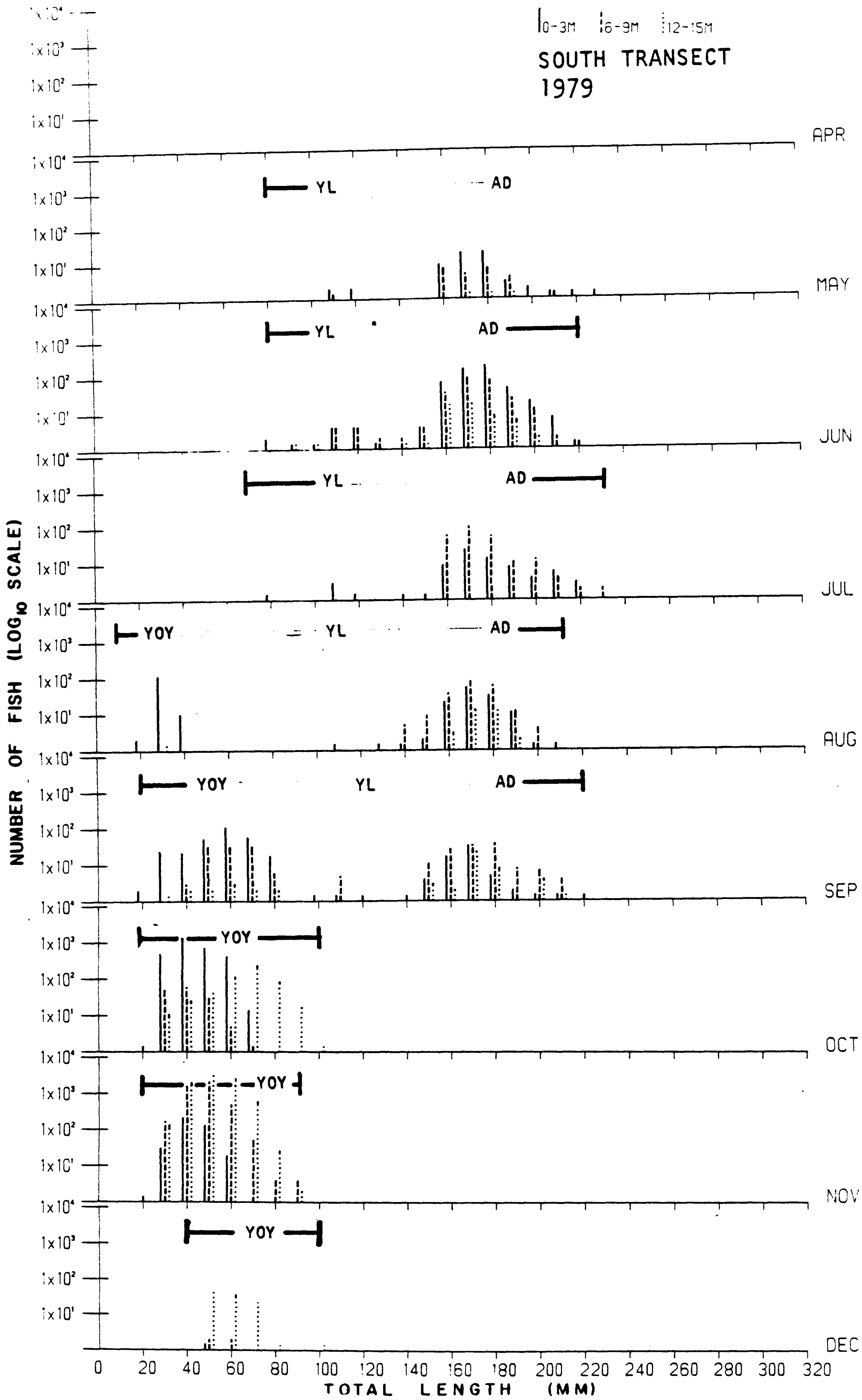

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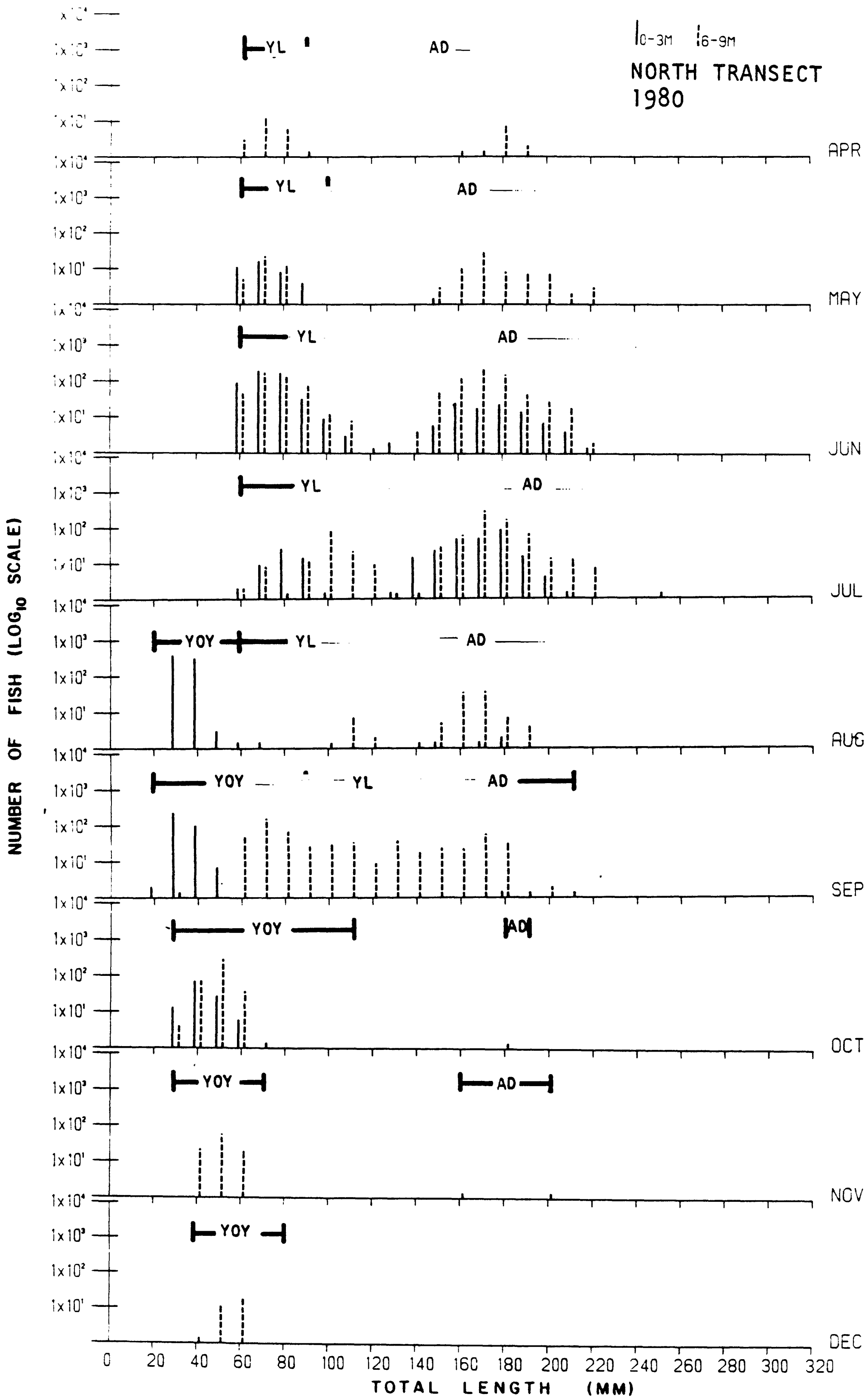

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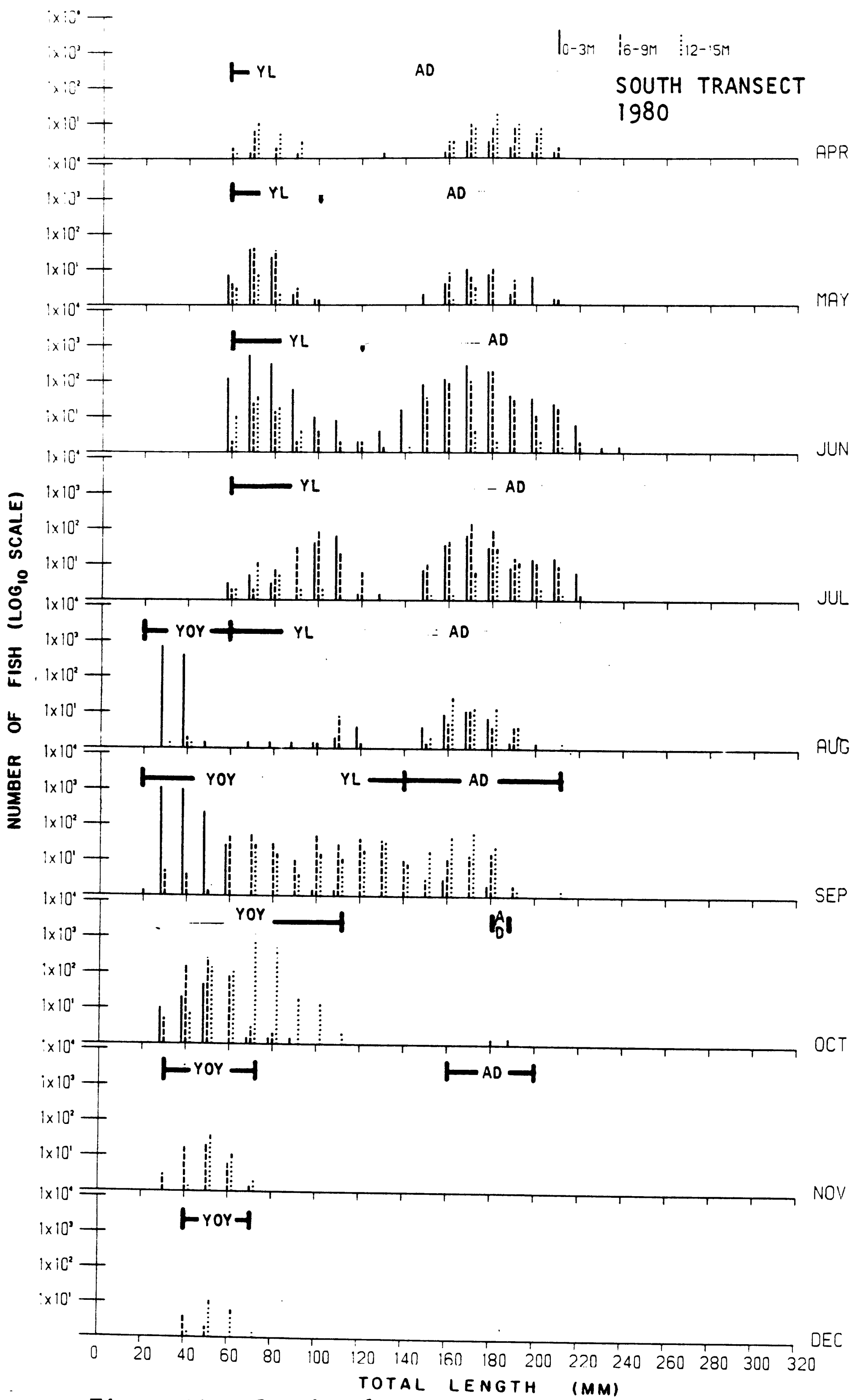


Fig. 21. Continued.

During August of all years, there was a definite tendency for YOY to be distributed in the nearshore beach zone (Fig. 21). Without exception at least 99% of YOY captured in August from 1977 to 1980 were seined at beach stations. Modal length of YOY alewives caught in August each year ranged from 40 mm in 1977 to 30 mm in 1978-1980. The slightly higher modal length of YOY caught in August 1977 may substantiate the contention that some of these YOY were spawned early in Pigeon Lake or the discharge canal and moved into the adjacent Lake Michigan beach zone. It is also possible that this slight difference in modes was caused by variation in growth rates between years. A close examination of 1978 length-frequency data for YOY captured in August also revealed that although modal length was 30 mm, nearly as many fish were in the 40-mm length interval.

During September YOY alewives were primarily distributed from the beach to 3-m depths (Fig. 21). The most marked nearshore distribution of YOY in September was observed in 1977 when 99% of the YOY captured were taken at beach and 3-m stations. During September 1977 there were also 10 times as many YOY captured (over 15,000) than in September of any other year. The reason for this extraordinary occurrence of YOY nearshore in September 1977 may be related to water temperature differences between stations. During September of other study years, 1978-1980, water temperatures at 6- and 9-m stations were not significantly different from beach and 3-m stations (Fig. 22), which apparently allowed for a wider distribution of YOY to the 6- and 9-m contour. During September of these years 7-33% of the YOY catch was taken at 6- and 9-m depths. During 1977, however, nearshore bottom temperatures were substantially higher than bottom temperatures at 6- and 9-m stations (Fig. 22), resulting in a concentration of YOY in the nearshore zone. The contention that YOY alewives were attracted to warmer water temperatures is substantiated by the observed correlation of highest YOY alewife catch at beach station Q (south discharge) in September 1977 when this station exhibited highest water temperatures available (15.5 C) among Lake Michigan beach stations. Brandt (1980) reported that YOY alewives near Grand Haven (17.5 km north of Port Sheldon) were mainly captured in the warmest water available during September. Our data indicate that during years when the inshore area of Lake Michigan is more or less isothermal, YOY distribution is generally at depths of 9 m or less. Limited distribution to the 12- and 15-m depths was also indicated during 1979 and 1980 (Fig. 21). During years when either the natural cooling of Lake Michigan occurs or an upwelling results in marked temperature differences between depth contours, YOY alewives will probably remain in the warmest water temperatures available. Brandt (1980) suggested that their September YOY alewife distribution was independent of depth and primarily related to water temperature.

The modal lengths of YOY taken in September varied from 30 mm in 1980 to 60 mm in 1977 and 1979. A definite bimodal distribution was indicated in September 1977, the modes of which were primarily separable by station. The mode of YOY caught in September 1977 at station Q (south discharge) was 60 mm, while the mode at other beach stations (P, south reference and R, north discharge) was 40 mm. This observed difference in modes may reflect the increased ability of larger YOY to maintain themselves at the highest water temperature available. Another possible explanation for the difference in

modes among beach stations may be that those YOY sampled at station Q in September 1977 were part of the cohort spawned in the discharge canal earlier in the season which subsequently moved into the adjacent Lake Michigan beach zone.

It is during October that the first substantial movement of YOY to depths greater than 9 m usually occurred (Fig. 21). In all years sampled, the October YOY catch taken at 6- and 9-m stations ranged from 12% of the total monthly catch in 1979 to 40% in 1978, while at 12- and 15-m stations this percentage ranged from 12 in 1979 to 72 in 1980. During 1977 when the 18- and 21-m contours were sampled, 27% of all YOY captured were trawled at these stations (Jude et al. 1978). While a definite offshore movement of YOY alewives in October was indicated in all years, the extent of the movement was variable. In 1980 as low as 6% of the YOY were captured at beach and 3-m stations, while in 1979 as high as 76% were taken nearshore. The extraordinary occurrence of YOY in the nearshore zone during October 1979 may be related to the delayed spawning peak of alewives that year, resulting in a prolonged stay in nursery areas.

In most years, during October sampling the temperature differences between stations were subtle and temperature preference patterns were not obvious. For whatever reason, however, a distinct offshore movement of YOY alewives was indicated in all years (Fig. 21). The one sample collected at 21 m in October 1977 suggests the possibility that many YOY leave the study area for greater depths (Jude et al. 1978). An examination of modal lengths of YOY in October gives some indication that larger YOY migrate offshore ahead of smaller YOY. For years 1977, 1979 and 1980 the modal length for those larvae captured at the beach and 3-m stations was 40 mm, while modal lengths for those YOY caught at more offshore stations was 60 or 70 mm. Modes of 60 mm were observed at all station combinations in 1978; however, there was a bimodal distribution at beach and 3-m stations with the additional mode at 30 mm.

During November, a continued offshore movement of YOY was indicated in all years. The extent of the offshore movement, was variable. During 1977 when 18- and 21-m stations were sampled in addition to beach to 15-m stations, 64% of the YOY were captured at 21 m (Jude et al. 1978). During 1978, 70% of the YOY catch was made at depths of 6 and 9 m, while 90% of the YOY catch during 1979 was taken about equally at the 6- to 9-m and 12- to 15-m contours. An even more extensive offshore migration in November 1980 was indicated by the comparatively low catches of YOY in the study area.

Without exception for 1977-1979 modal lengths of YOY caught at more offshore station groupings were larger than those YOY caught at more inshore stations. Modal comparisons during November 1980 were precluded by the small catch of YOY. These data further indicate that larger YOY do migrate offshore ahead of smaller YOY. In all years, water temperature did not correlate with any trend of YOY abundances.

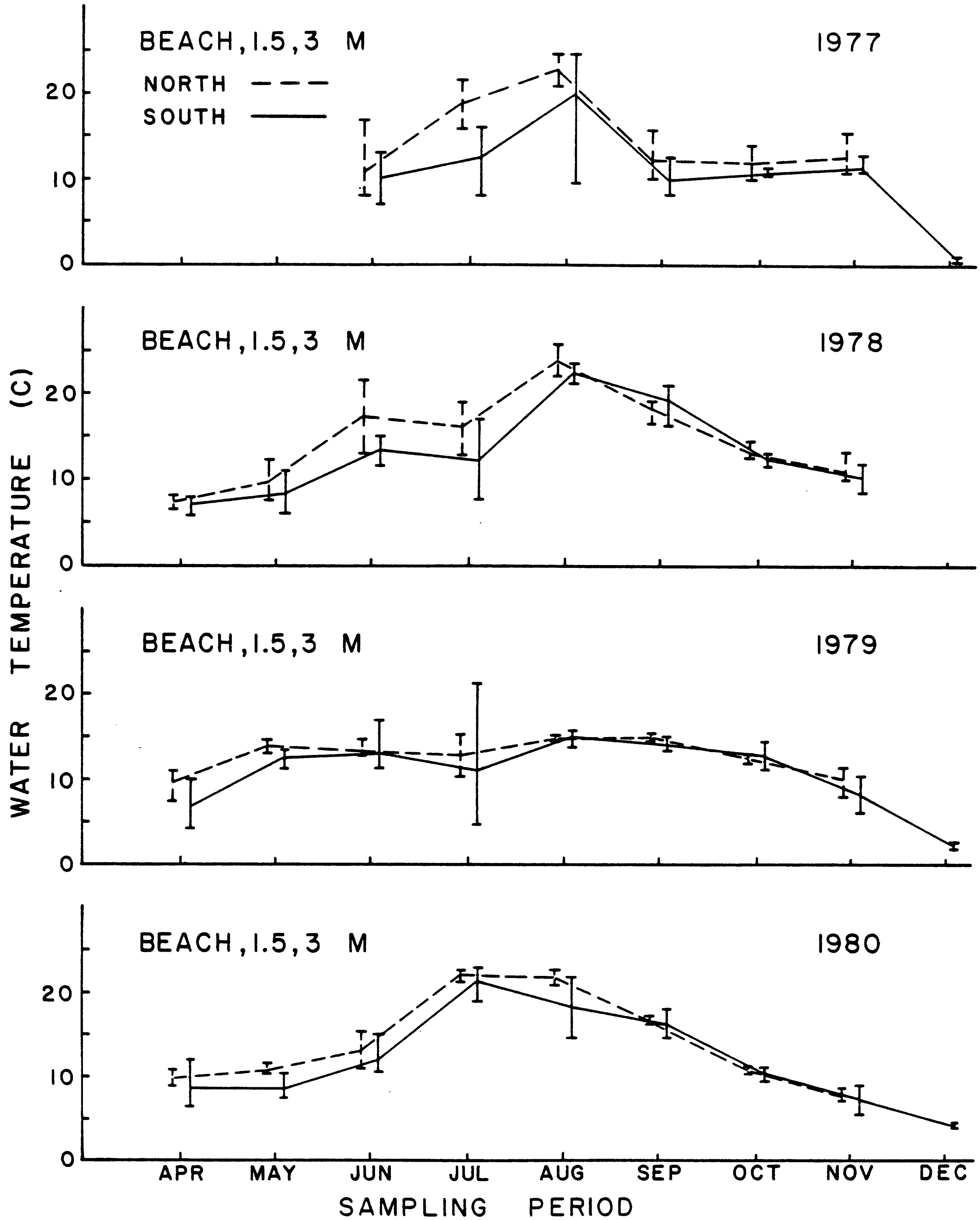
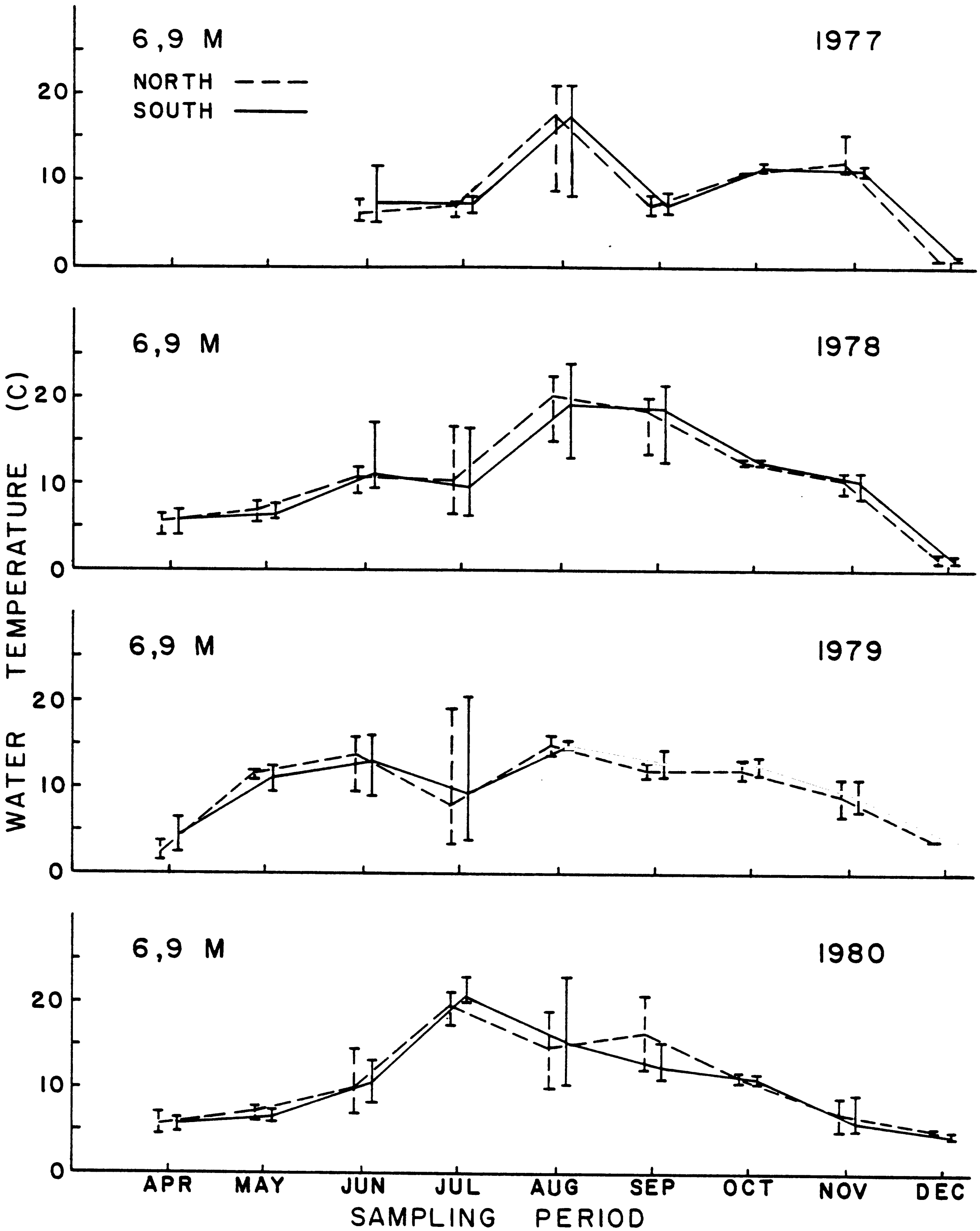


Fig. 22. Mean bottom temperatures observed during monthly sampling from June to December 1977 and April to December 1978-1980 in eastern Lake Michigan, near the J.H. Campbell Plant. Vertical bars denote temperature range.



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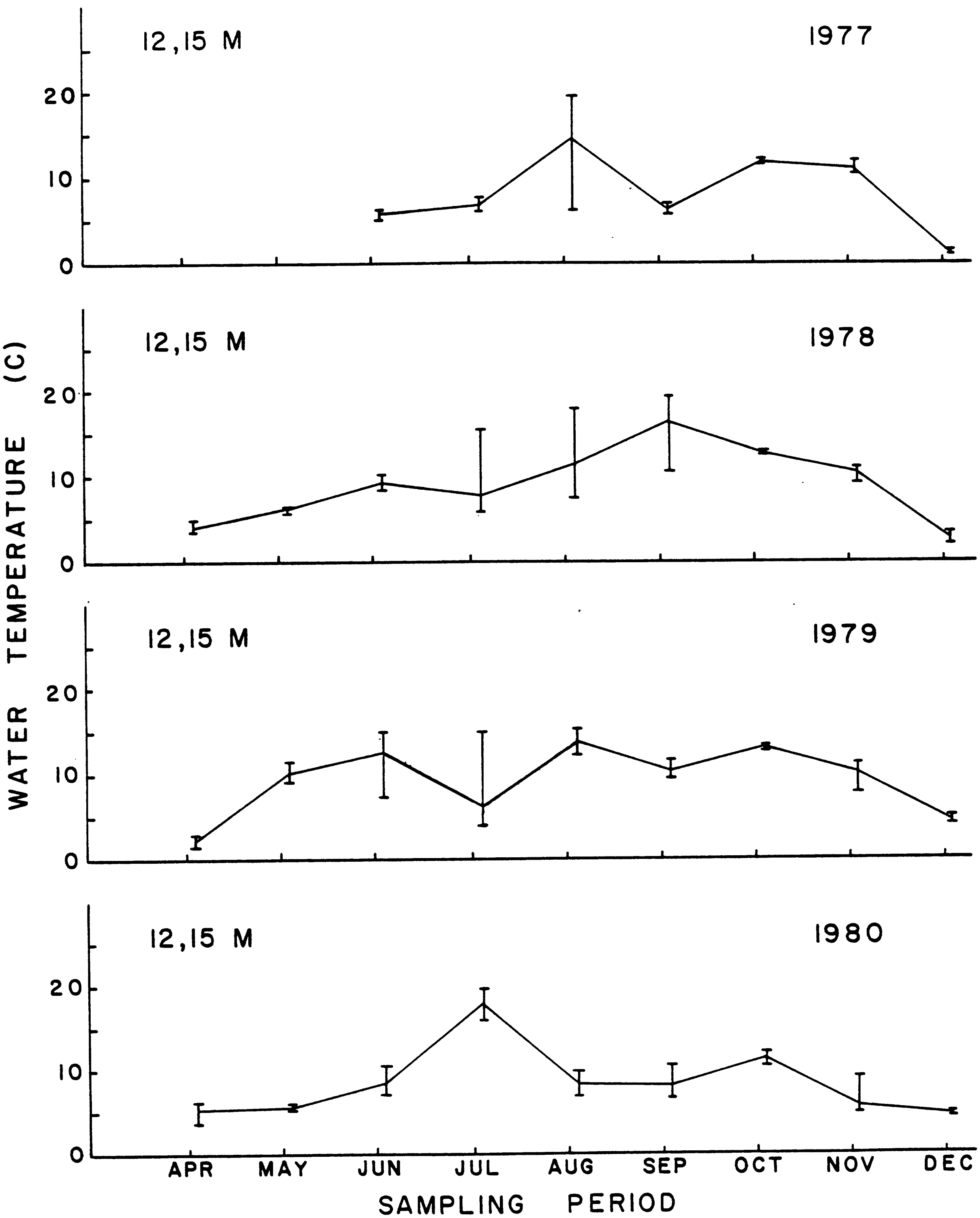


Fig. 22. Continued

Migration of YOY alewives from the inshore water of Lake Michigan near the Campbell Plant was generally completed by December of each year. With the exception of low numbers of smaller YOY (modal lengths 50-60 mm) caught at beach to 15-m stations in December 1979 and 1980, no substantial concentrations of YOY were recorded in the study area during December.

Yearlings--

In general, catches of yearling alewives near Port Sheldon were lowest of the three age-groups sampled. This concurred with Jude et al. (1980) who noted that yearlings were least abundant in samples taken near Bridgman, Michigan (108 km south of Port Sheldon). Yearling alewives are reportedly more pelagic and reside primarily offshore (Brown 1972; Wells 1968).

The exception to low catches of yearling alewives occurred during 1980. In contrast to previous years' (1978 and 1979) sampling in which no yearling alewives were caught during April, effort during April 1980 indicated a limited inshore distribution of yearlings (Fig. 21). This inshore presence continued to occur in May 1980 when over 200 yearlings were caught inshore, compared with less than 25 caught in May 1978 and 1979. During May 1980 more than 95% of the yearling alewives were caught at beach to 9-m stations (Fig. 21). A continued inshore movement and increased abundance of yearlings were observed in June 1980 when over 2000 yearlings were caught primarily at beach to 9-m stations. The total number of yearling alewives caught in June 1980 exceeded the total number of yearlings caught in all months sampled from 1977 to 1979 combined, and represented an extraordinary inshore migration of yearlings in late spring 1980. Although the reason for this extensive inshore migration of yearlings is unknown, it may be related to the previous year's abnormal delay in the spawning peak for alewives. The prolonged and somewhat delayed spawning season of 1979 seems to have resulted in a group of smaller yearlings in 1980. During 1977-1979 the modal lengths of the few yearlings collected which returned to the inshore zone in June were 100 mm, 90 mm, and 120 mm respectively. Length-frequency data for yearling alewives caught in June 1980 indicated a mode of 70 mm. It may be that smaller yearlings are behaviorally adapted to return again to the inshore zone during spring and summer warming, while larger yearlings remain more offshore and are more pelagic. During all years, most returning yearlings were caught at depths to 9 m.

Compared with previous years, the catch of yearling alewives during August 1980 was still considerably larger, exceeding the August catch of all previous years combined. Modal lengths however were similar among years ranging from 90 to 120 mm. In all years relatively higher catches were made at 6- and 9-m stations in August. This trend was continued during September sampling. Although these data may appear to indicate a preference for the 6- and 9-m contours during August and September of most years, a more detailed scrutiny of the data indicated alewives moved offshore. The majority of yearlings caught during August and September of most years were taken in surface gill nets which were only fished at 6-m stations, except in 1977.

In all years sampled, no yearlings were caught from October to December suggesting that yearlings overwinter at depths greater than 21 m. Offshore migration of yearlings was generally completed by late October of most years.

Adults--

From January until mid-April adult alewives were generally distributed offshore in deeper water (greater than 15 m) (Reigle 1969; Wells 1968). As inshore water warms, adult alewives typically move inshore for an extended period of spawning from May to September. Periodic upwellings in spring and summer months result in temporary offshore or alongshore movements and interruption of spawning.

<u>Seasonal distribution</u>--

April and May--The first indication of an annual inshore migration of adult alewives near the Campbell Plant occurred in April or May (Fig. 21). During the 2 yr when adult alewives were caught in April (1978 and 1980) catches were small (less than 100 fish). Gonad data (Fig. 23) indicated that none of the adult alewives taken in April 1978 or 1980 had well developed gonads, thus we believe that spawning was not occurring at this time. These data, along with larval fish data, indicate that alewife spawning in the vicinity of Port Sheldon generally does not occur prior to May.

Alewives exhibited a more substantial inshore movement in May when compared with April during all years sampled (Fig. 21). Although accurate numerical comparisons among the depth groupings were confounded by the differential catch effort at each grouping, there was a clear indication that adult alewives in May showed a major concentration at depths of 9 m or less (Fig. 21).

Gonad data showed as high as 30% of the alewives caught in May 1980 had well developed gonads or were ripe-running (Fig. 23). A small portion of the adult catch in May 1978 and 1979 were spent (Fig. 23). Collectively these data indicate that alewife spawning in Lake Michigan near Port Sheldon usually initiates during May, however a large part of the population sampled in May of all 3 yr was not ready to spawn.

June--With the exception of June 1978, when less than 300 adult alewives were caught inshore (15 m or less), the catch of adult alewives in June of other years exceeded 1000 alewives, and in June of 1977 and 1980 exceeded 2000 adult alewives (Fig. 21). The vast majority of adult alewives taken in June of any year were taken at 9 m or less (Fig. 21). Gonad data indicated that in all years over 50% of those adult alewives caught in June had well developed gonads or were ripe-running (Fig. 23). Generally between 5% and 20% of adult alewives caught in June were spent (Fig. 23). These data indicate that spawning activity toward the latter part of June in all years was intensified compared with May. This is supported by larval fish data indicating a hatching peak in early July of all years.

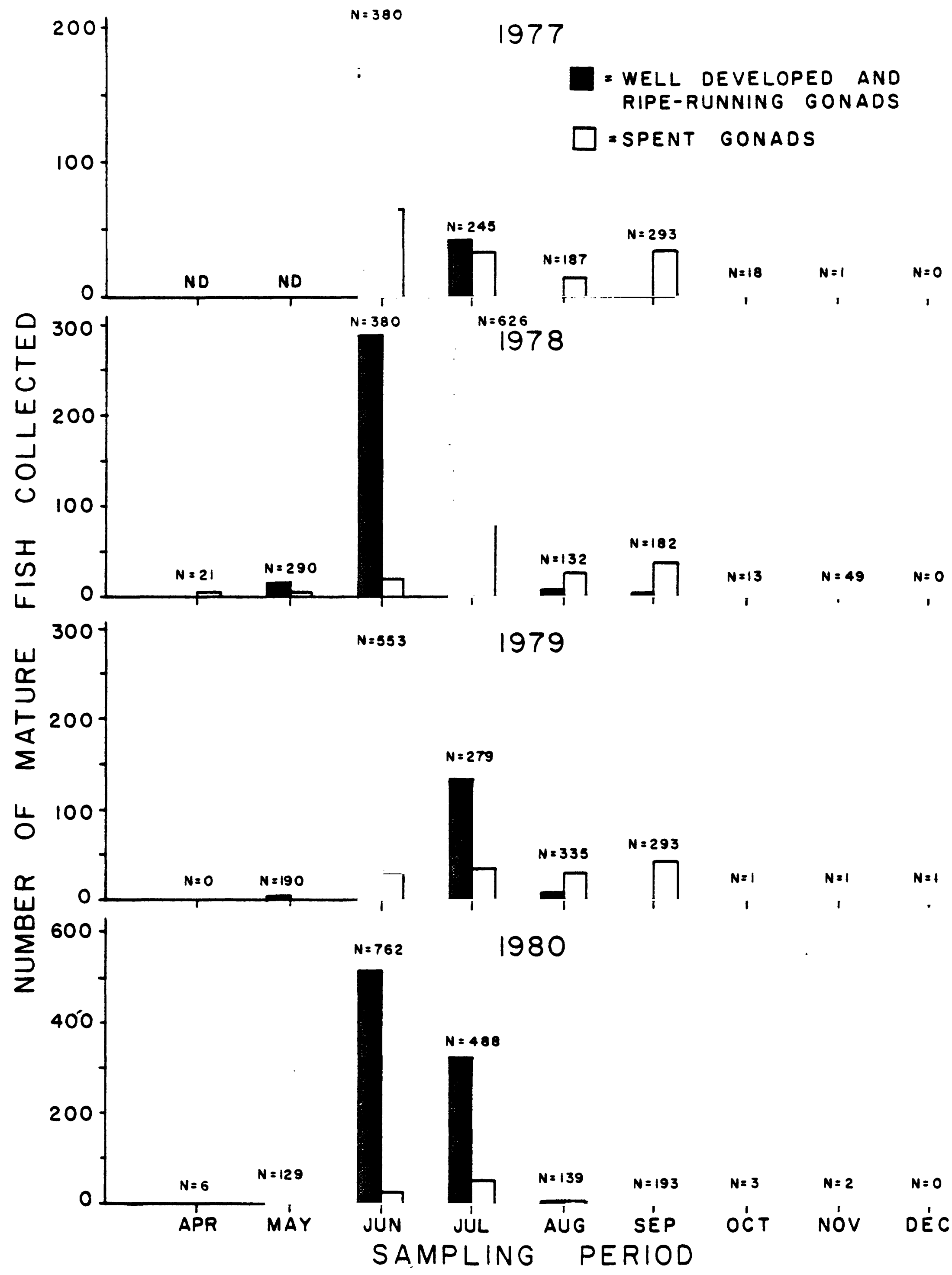


Fig. 23. Number of mature alewives with well developed, ripe-running and spent gonads collected monthly during June-December 1977 and April-December 1978-1980 near the J. H. Campbell Plant, eastern Lake Michigan. N = total number of mature alewives caught per month.

July--As can be inferred from larval alewife data, July is typically the time of most intensive alewife spawning near the Campbell Plant. During July 1978 and 1980 when water temperatures were highly conducive to spawning, catches of adult alewives were high (over 3200 and over 1300 respectively) in the inshore zone. During 1977 and 1979 when the warming trend was interrupted by upwellings, the catch of alewives in either year did not exceed 700 adults, suggesting that adult alewives had to some degree moved offshore in response to the upwelling. In all years the distribution of those alewives that did occupy the inshore zone was primarily at depths of 9 m or less.

With the exception of July 1977, over 50% of those alewives caught in July of other years showed advanced gonad conditions or were ripe-running (Fig. 23). In all years between 10% and 15% of all adult alewives examined in July were spent (Fig. 23). These data suggest that we observed a progression in gonad conditions through the spawning season. Individuals with well developed gonads or which were ripe-running were still present in relatively high proportions as was found in June, while generally higher proportions of spent individuals were being caught compared with June of the same years. The extraordinary low proportion of adult alewives with advanced gonad condition in July 1977 (less than 20%) was probably due to the upwelling which occurred then and may have induced potential spawners to temporarily move offshore.

August--The catch of adult alewives inshore in August of all years exhibited a marked decline compared with respective July periods (Fig. 21). This indicated that generally an offshore migration by adults from the inshore zone near Port Sheldon began in August. Relative distribution of those adult alewives that had remained inshore exhibited some variation. During August 1979 the distribution of adult alewives in the inshore zone was primarily at 9 m or less (Fig. 21). During 1977 when depths to 21 m were sampled, higher densities of alewives were observed at the beach and 3-m depths and the 18-m station compared with the intermediate 6- to 15-m depth groupings. Sampling in August 1978 and 1980 indicated that alewives were primarily distributed at depths of 6 m or greater (Fig. 21).

Gonad data from all years showed only a small proportion of those adult alewives examined in August (less than 5% - Fig. 23) had yet to spawn, while an increased percentage of adult alewives caught in August of all years, except 1980, were spent. It is possible that the more advanced progression of the adult alewife population through the spawning season was responsible for the more random distribution of adults in the inshore zone in August, compared with the more pronounced preference for depths 9 m or less which was indicated in July of all years.

September--In most years the abundance of adult alewives in September catches at depths of 15 m or less did not significantly differ from August collections. The exception to this pattern was during September 1977 when there was a two-fold increase in the adult catch in September compared with August of that year. During all years, September sampling indicated that adult alewives were less concentrated in the nearshore zone compared with August, however the extent of their offshore migration was variable (Fig. 21). The adult alewife catch in September of all years indicated that there were no

fish with well developed gonads or which were ripe-running (Fig. 23). It is likely that alewife spawning for the most part was completed by September. Larval fish data do indicate, however, that limited alewife spawning did occur into September 1979. During years when extended periods of upwelling delayed the major spawning period for alewives, more intense spawning into the later extremes of the spawning season were observed.

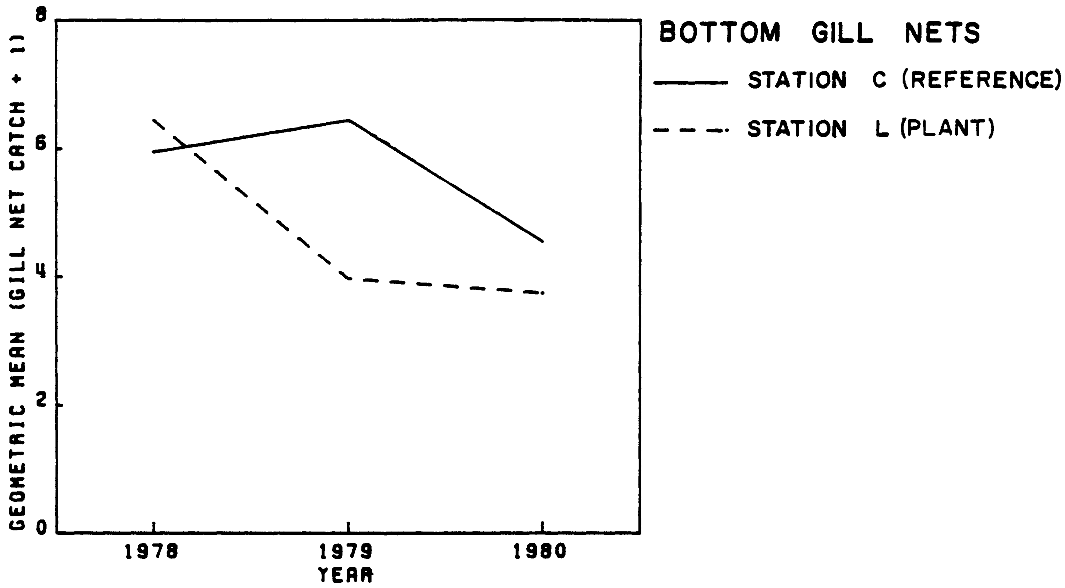
October, November and December--From October to December adult alewives were only rarely caught in the inshore zone near the Campbell Plant. A massive offshore movement of adult alewives probably occurs coincident with the rapid autumn cooling of the inshore zone in late September to early October in most years.

Plant Effects--

A Wilcoxon signed ranks test combining data from all 4 yr indicated that there were no significant differences in the densities of larval alewives collected between north and south transects. Year to year variability in relative abundances of larval alewives between transects was, however, clearly demonstrated by annual Wilcoxon signed ranks testing. The combined monthly data for 1978 indicated that significantly higher densities of larval alewives were observed at the south transect compared with the north transect for that year (α = .0158). Conversely, during 1980, combined monthly data indicated significantly higher densities of larval alewives at the north transect compared with south transect stations (α = .0002). For both 1977 and 1979 no significant differences in the abundances of larval alewives between transects was indicated. These data collectively suggest that a single year transect comparison in 1981 will be inconclusive in ascertaining the effect of Unit 3 operation on larvae, since there is approximately equal probability that in any 1 yr north or south transect stations would have significantly higher or lower densities of larval alewives. These data also suggest that operation of Units 1 and 2 is not significantly affecting the abundances of larval alewives in the vicinity of Port Sheldon.

Over the 4 yr, the catch of adult and juvenile alewives did not significantly differ between north and south transect stations based on bottom gill net, surface gill net, seine and trawl data (Figs. 24-27, Tables 19-26). Simplified north transect-south transect comparisons were confounded by a variety of interactions (Tables 19-26); however, these interactions are primarily related to life history peculiarities of alewives previously explained. The greatest disparity in catch of adult and juvenile alewives between transects occurred in 1978, when an extraordinarily high trawl catch at the north transect in November caused the AREA factor in the ANOVA to almost approach significance (Fig. 27, Table 26). Other than this spurious event, we detected no significant buildup or depletion of fish at either transect. We thus feel that the thermal plume is not causing any significant shift in the distribution of adult and juvenile alewives near the Campbell Plant.

ALEWIFE



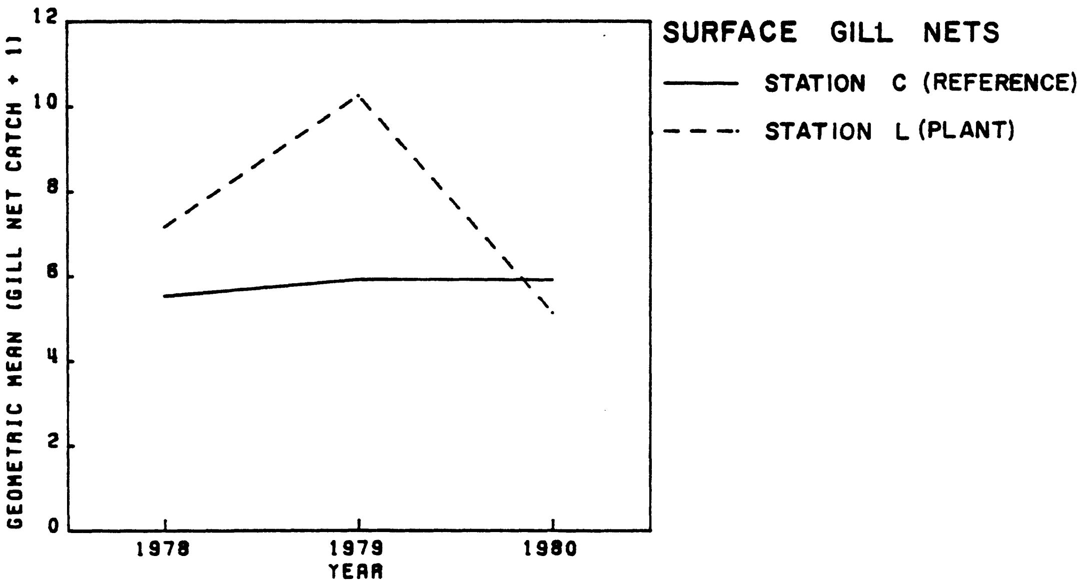


Fig. 24. Geometric mean number plus one of alewives caught in bottom gill nets and surface gill nets at stations C (6 m, south) and L (6 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1978 through 1980. Graphs illustrate the YEAR X STATION interaction.

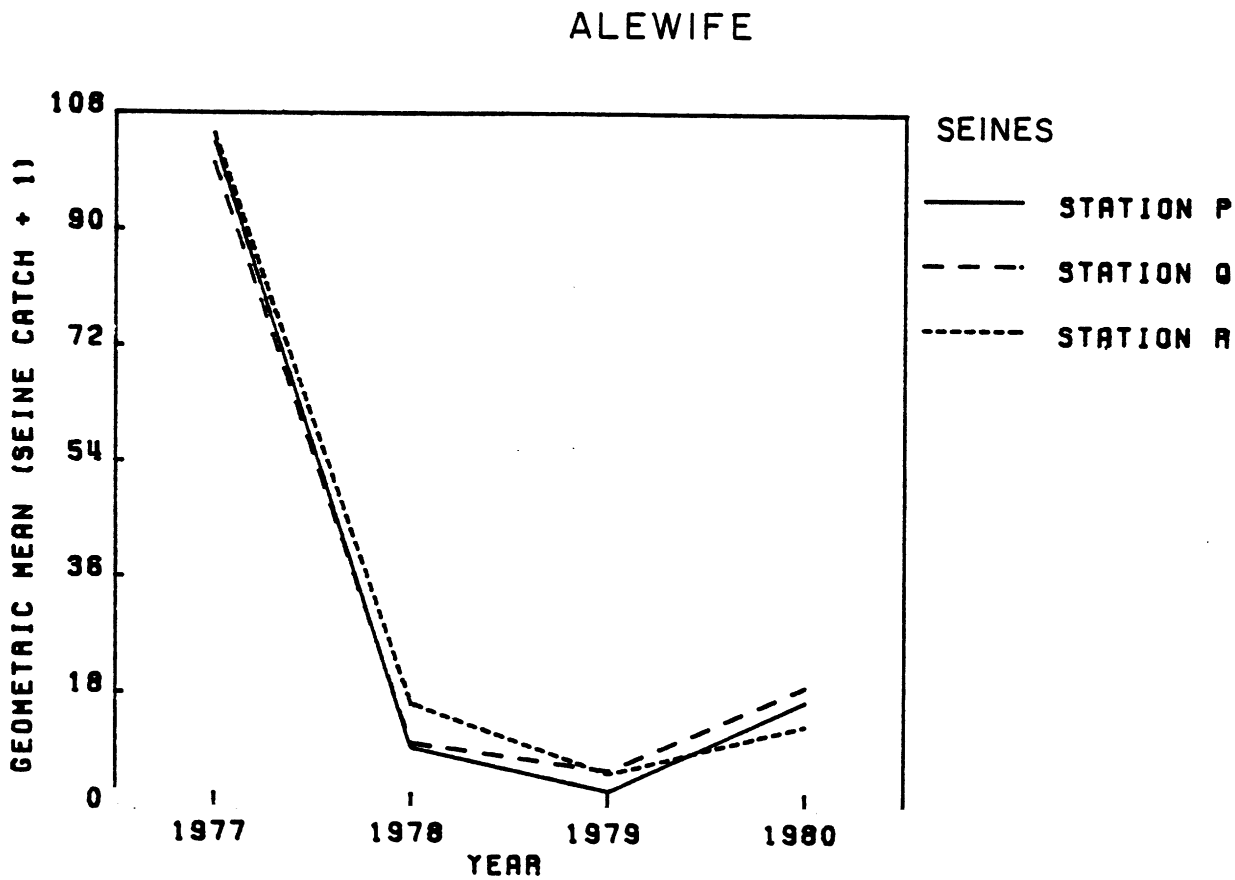


Fig. 25. Geometric mean number plus one of alewives caught in seines at beach stations P (south reference), Q (south discharge) and R (north discharge) near the J. H. Campbell Plant, eastern Lake Michigan, 1977 through 1980. Graph illustrates the YEAR X STATION interaction.

Although an estimate of larval alewives lost to entrainment by Unit 3 must await analysis of data from 1981 entrainment sampling, a certain amount of predictability is allowed from observation of trends during preoperational years 1977-1980. Highest entrainment of larval alewives will probably coincide with the alewife hatching peak in any year. In most years, this hatching peak occurred in July, but during years of extensive upwellings, the hatching peak may be delayed until August. During alewife hatching peaks, larval alewives were generally distributed to depths of at least 15 m. We believe that during hatching peaks, most alewives present will be newly

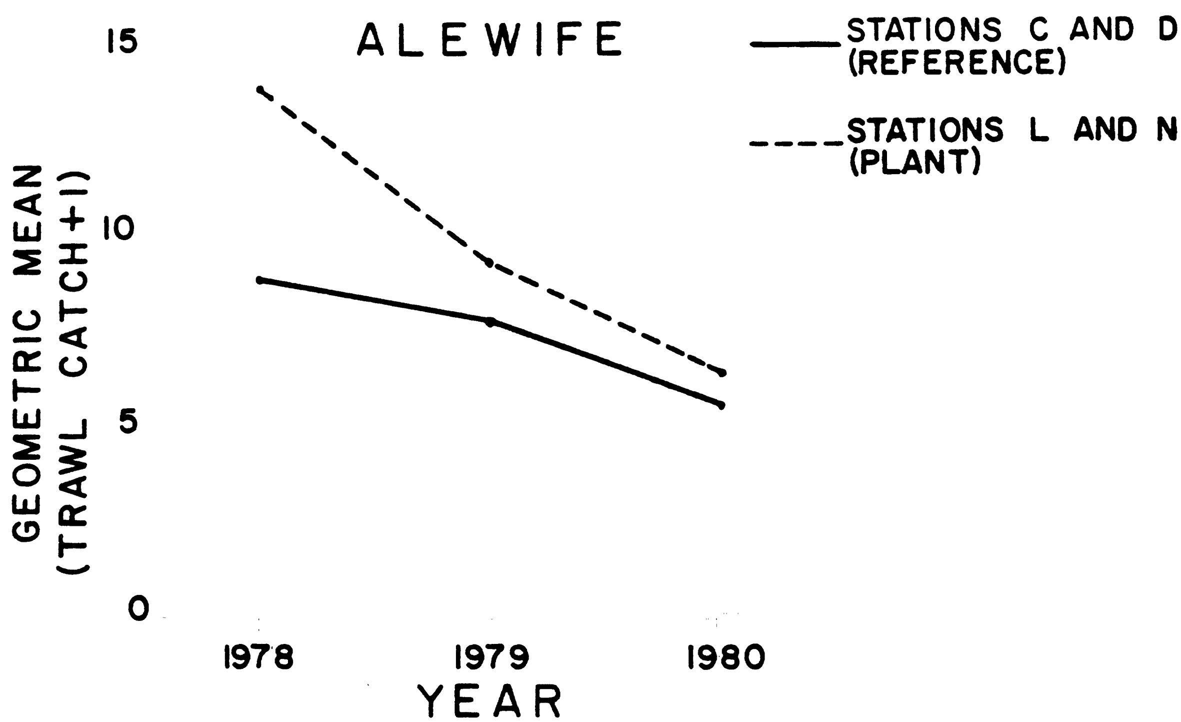


Fig. 26. Geometric mean number plus one of alewives caught in trawls at stations C (6 m, south), D (9 m, south), L (6 m, north) and N (9 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1978 through 1980. Graph illustrates the YEAR x AREA interaction.

hatched, and thus be passively carried by water currents. It is doubtful at this point whether the majority of these newly hatched larval alewives will be able to avoid the intake current at the Unit 3 structures.

There are two factors which will tend to attenuate entrainment loss through Unit 3, although the degree of attenuation in each case will be highly variable. Our data indicate that location of the Unit 3 intake structures at 11 m will result in less entrainment loss compared to water withdrawal at a shallower depth contour (see Tables 15-18 also). Over the 4 yr sampled, there was a general tendency for larvae, at times other than an intense hatching peak, to be more concentrated at depths of 9 m or less. This trend was particularly evident during times of upwelling.

A second factor which will tend to limit entrainment of larval alewives at Unit 3 relates to the location of the intake structure in the water column. In the majority of cases, surface strata at the 12- and 15-m stations had higher densities of larval alewives than did bottom strata. Thus, as opposed to a surface withdrawal of cooling water, the bottom water withdrawal (lower 3-4-m strata) of Unit 3 will probably entrain fewer alewife larvae.

Table 19. Analysis of variance summary for alewives caught in bottom gill nets at stations C (6 m, south) and L (6 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1977 through 1980. Data for July through September were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	3	0.4311	4.5213	0.0072*
Month	2	0.5325	5.5856	0.0066*
Station	1	0.1345	1.9354	0.1706
Time	1	0.4584	4.8084	0.0332
Y x M	6	1.0680	11.2023	<0.0001**
Y x S	3	0.5729	6.0091	0.0015*
M x S	2	0.0128	0.1337	0.8751
Y x T	3	1.1570	12.1350	<0.0001**
M x T	2	2.2481	23.5794	<0.0001**
S x T	1	0.0024	0.0256	0.8736
Y x M x S	6	0.3497	3.6678	0.0045*
Y x M x T	6	1.5296	16.0438	<0.0001**
Y x S x T	3	0.2507	2.6290	0.0608
M x S x T	2	0.5266	5.5438	0.0068*
Y x M x S x T	6	0.4792	5.0260	0.0005**
Within cell error	48	0.0953		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

Table 20. Analysis of variance summary for alewives caught in bottom gill nets at stations C (6 m, south) and L (6 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1978 through 1980. Data for June through September were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	2	0.3138	3.5343	0.0354
Month	4	1.0745	12.1022	<0.0001**
Station	1	0.2268	2.5540	0.1153
Time	1	1.1024	12.4165	0.0008**
Y x M	8	0.9413	10.6019	<0.0001**
Y x S	2	0.1508	1.6982	0.1917
M x S	4	0.3139	3.5351	0.0118
Y x T	2	1.3593	15.3101	<0.0001**
M x T	4	1.6841	18.9681	<0.0001**
S x T	1	0.0600	0.6758	0.4143
Y x M x S	8	0.2784	3.1355	0.0050*
Y x M x T	8	1.4462	16.2881	<0.0001**
Y x S x T	2	0.7802	8.7868	0.0004**
M x S x T	4	0.6972	7.8525	<0.0001**
Y x M x S x T	8	0.1633	1.8395	0.0872
Within cell error	60	0.0888		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

Table 21. Analysis of variance summary for alewives caught in bottom gill nets at stations C (6 m, south), D (9 m, south), L (6 m, north) and N (9 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1980. Data for June through September were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Month	3	1.5686	20.9999	<0.0001**
Area	1	0.0489	0.6540	0.4247
Depth	1	1.5915	21.3055	0.0001**
Time	1	0.2649	3.5457	0.0688
M x A	3	0.1015	1.3591	0.2729
M x D	3	0.6812	9.1199	0.0002**
A x D	1	0.0023	0.0304	0.8627
M x T	3	4.2654	57.1026	<0.0001**
A x T	1	0.0884	1.1837	0.2847
D x T	1	0.7055	9.4455	0.0043*
M x A x D	3	0.3352	4.4869	0.0097*
M x A x T	3	0.2428	3.2506	0.0345
M x D x T	3	0.4068	5.4458	0.0039*
A x D x T	1	0.0469	0.6283	0.4338
M x A x D x T	3	0.2998	4.0134	0.0156
Within cell error	32	0.0747		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

Table 22. Analysis of variance summary for alewives caught in surface gill nets at stations C (6 m, south) and L (6 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1977 through 1980. Data for July through September were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	3	0.3633	2.0007	0.1337
Month	1	2.3445	12.9123	0.0011*
Station	1	0.0801	0.4412	0.5113
Time	1	18.1489	99.9537	<0.0001**
Y x M	3	0.2594	1.4285	0.2526
Y x S	3	0.2158	1.1883	0.3297
M x S	1	0.2384	1.3132	0.2603
Y x T	3	0.7154	3.9403	0.0169
M x T	1	0.0911	0.5018	0.4838
S x T	1	0.4537	2.4985	0.1238
Y x M x S	3	0.3922	2.1600	0.1121
Y x M x T	3	0.4723	2.6011	0.0691
Y x S x T	3	0.6412	3.5313	0.0257
M x S x T	1	0.5437	2.9946	0.0932
Y x M x S x T	3	0.8406	4.6298	0.0085*
Within cell error	32	0.1816		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

Table 23. Analysis of variance summary for alewives caught in surface gill nets at stations C (6 m, south) and L (6 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1978 through 1980. Data for May through September were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	2	0.2314	2.0504	0.1376
Month	4	0.8758	7.7611	<0.0001**
Station	1	0.2780	2.4634	0.1218
Time	1	38.2369	338.8459	<0.0001**
Y x M	8	0.2667	2.3637	0.0278
Y x S	2	0.2248	1.9923	0.1453
M x S	4	0.2075	1.8384	0.1333
Y x T	2	0.3456	3.0622	0.0542
M x T	4	0.1842	1.6320	0.1780
S x T	1	0.0774	0.6862	0.4107
Y x M x S	8	0.3870	3.4297	0.0026*
Y x M x T	8	0.3629	3.2161	0.0042*
Y x S x T	2	0.7753	6.8703	0.0021*
M x S x T	4	0.8569	7.5933	0.0001**
Y x M x S x T	8	0.4032	3.5729	0.0019*
Within cell error	60	0.1128		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

Table 24. Analysis of variance summary for alewives caught in seines at stations P (south reference), Q (south discharge) and R (north discharge) near the J. H. Campbell Plant, eastern Lake Michigan, 1977 through 1980. Data for June through September were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	3	15.6723	68.1479	<0.0001**
Month	3	11.2659	48.9874	<0.0001**
Station	2	0.2475	1.0762	0.3450
Time	1	0.5471	2.3789	0.1263
Y x M	9	2.0260	8.8185	<0.0001**
Y x S	6	0.2327	1.0120	0.4222
M x S	6	0.5030	2.1874	0.0507
Y x T	3	0.4469	1.9431	0.1278
M x T	3	12.1781	52.9540	<0.0001**
S x T	2	0.5807	2.5250	0.0854
Y x M x S	18	0.6467	2.8122	0.0006**
Y x M x T	9	1.8064	7.8549	<0.0001**
Y x S x T	6	0.6432	2.7967	0.0150
M x S x T	6	0.9522	4.1403	0.0010**
Y x M x S x T	18	0.8784	3.8193	<0.0001**
Within cell error	96	0.2300		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

Our investigations of the distribution of young-of-the-year (YOY) alewives, another group of alewives possibly subject to entrainment (see Schneeberger and Jude 1980) or impingement loss at Unit 3, indicate that maximum loss would be expected during October or November. At this time YOY were shown to exhibit an offshore movement. Prior to this time of year, as indicated by our trawl and seine catches, YOY remained primarily closer to shore at depths of 9 m or less, and often exhibited an extreme inshore (beach to 3 m) distribution.

Although maximum loss of YOY alewives might be expected to occur in October and November based on distributional data, an accurate prediction of the magnitude of loss is not possible. Since YOY alewives could probably avoid the predicted intake current (maximum through-slot velocity 15.2 cm/s), behavioral factors rather than mere distributional coincidence will be responsible for any YOY alewife loss.

Rainbow Smelt

Introduction--

Rainbow smelt populations in Lake Michigan, as indicated by commercial catches, fluctuated widely during the period 1931-1972 (Wells and McLain 1973). Near the J. H. Campbell Plant, rainbow smelt abundance appeared to be steadily increasing during 1977-1980. Rainbow smelt accounted for 16.4%, 27.8%, 38.4% and 43.6% of the total juvenile and adult fish catches in Lake Michigan in 1977, 1978, 1979 and 1980 respectively (Table 10). During 1977-1978 smelt was the second-most numerous species caught in the study area after alewife. In 1979-1980 smelt ranked first in numerical abundance over all juvenile and adult fish collected. Rainbow smelt larvae were, however, less frequently caught than larvae of other abundant species in the study area, such as alewife and spottail shiner. Density of larval rainbow smelt varied considerably during 1977-1980 (Figs. 27-36). Highest densities of smelt larvae were observed during 1979. Rainbow smelt generally migrate inshore during spring and return to deeper water during fall and winter. Early life stages of rainbow smelt were caught in plankton nets and sleds from May to August. YOY larger than 25.4 mm and yearlings were mostly caught in trawls. In addition, fish in these two size groups were occasionally found in seines. Adult smelt occurred mostly in bottom gill nets and trawls.

Larvae--

Seasonal distribution--

May--In 1977 fish larvae sampling was not performed during April and May. During 1977 smelt larvae were first collected in June (Fig. 27). During 1978-1980, smelt larvae first occurred in the study area from 14 to 19 May (Figs. 28-36). Weekly entrainment sampling conducted at the Campbell Plant during 1978 and 1979 (Jude et al. 1979a; Jude et al. 1980) captured no smelt larvae during early May suggesting that larvae collected from 14 to 19 May were among the first brood of smelt larvae in the study area during 1978-1980. Near the Cook Plant, southeastern Lake Michigan, smelt larvae were first

Table 25. Analysis of variance summary for alewives caught in trawls at stations C (6 m, south) and L (6 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1977 through 1980. Data for June through November were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	3	0.5221	3.0635	0.0318
Month	5	7.3258	42.9810	<0.0001**
Station	1	0.3768	2.2106	0.1403
Time	1	1.3861	8.1324	0.0053*
Y x M	15	3.0990	18.1822	<0.0001**
Y x S	3	0.2179	1.2782	0.2863
M x S	5	0.2823	1.6561	0.1527
Y x T	3	2.2918	13.4461	<0.0001**
M x T	5	0.5020	2.9454	0.0162
S x T	1	0.0627	0.3681	0.5455
Y x M x S	15	0.4022	2.3600	0.0063*
Y x M x T	15	0.9374	5.5001	<0.0001**
Y x S x T	3	0.6514	3.8216	0.0124
M x S x T	5	0.4868	2.8560	0.0190
Y x M x S x T	15	0.4211	2.4704	0.0042*
Within cell error	96	0.1704		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

observed during 26-27 April in 1973 and 2-3 May in 1974 (Jude et al. 1979b). Late appearance of smelt larvae near the Campbell Plant was probably due to a late spawning run caused by lower water temperatures in this part of Lake Michigan during spring (see Adult-this section). Water temperatures ranged from 7.4 to 12 C during 18-24 April 1974 at the Cook Plant (Jude et al. 1979b) and from 3.5 to 7 C during 21-22 April 1980 (Appendixes 5 and 6) near the Campbell Plant. Lower temperatures at the Campbell Plant may have also delayed hatching of smelt larvae. Incubation time of smelt eggs varies inversely with water temperatures. McKenzie (1964) reported an incubation period of 29 days at 6 to 7 C, 25 days at 7.1 to 8.5 C and 19 days at 9 to 10 C. Cooper (1978) observed smelt hatching 8 to 9 days after fertilization at a mean water temperature of 16.5 C. At Ludington, located approximately 120 km north of the Campbell Plant on eastern Lake Michigan, smelt larvae were first collected around mid-May in 1978 (Liston et al. 1980).

Rainbow smelt larvae collected during May ranged from 5 to 8 mm during 1978-1980 (Figs. 28-36). Mean length of smelt larvae collected during 14-16 May 1978, 16-17 May 1979 and 19-20 May 1980 was 6.0, 5.5 and 5.8 mm respectively indicating that most larvae collected during mid-May were newly hatched (Scott and Crossman 1973; Cooper 1978). Smelt larvae collected in the shallow area (beach-3 m) and those found at deeper water (6-15 m) were in the same size range (Figs. 28-36).

Table 26. Analysis of variance summary for alewives caught in trawls at stations C (6 m, south), D (9 m, south), L (6 m, north) and N (9 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1978 through 1980. Data for June through November were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	2	1.7032	11.1799	<0.0001**
Month	5	18.7503	123.0799	<0.0001**
Area	1	0.8984	5.8970	0.0164
Depth	1	0.4830	3.1703	0.0771
Time	1	0.0006	0.0037	0.9517
Y x M	10	5.4579	35.8262	<0.0001**
Y x A	2	0.1240	0.8137	0.4452
M x A	5	0.6012	3.9463	0.0022*
Y x D	2	0.5282	3.4674	0.0338
M x D	5	0.7443	4.8857	0.0004**
A x D	1	0.0914	0.5997	0.4400
Y x T	2	6.9363	45.5308	<0.0001**
M x T	5	1.4837	9.7391	<0.0001**
A x T	1	0.3565	2.3401	0.1283
D x T	1	2.7351	17.9533	<0.0001**
Y x M x A	10	0.4361	2.8626	0.0028*
Y x M x D	10	0.2113	1.3872	0.1917
Y x A x D	2	0.3357	2.2035	0.1141
M x A x D	5	0.3997	2.6236	0.0265
Y x M x T	10	1.5489	10.1670	<0.0001**
Y x A x T	2	0.9170	6.0190	0.0031*
M x A x T	5	0.3204	2.1029	0.0684
Y x D x T	2	0.0082	0.0538	0.9477
M x D x T	5	0.4191	2.7513	0.0209
A x D x T	1	0.1006	0.6604	0.4177
Y x M x A x D	10	0.5802	3.8083	0.0001**
Y x M x A x T	10	0.5921	3.8868	0.0001**
Y x M x D x T	10	0.1376	0.9033	0.5319
Y x A x D x T	2	0.2625	1.7230	0.1822
M x A x D x T	5	0.3363	2.2074	0.0567
Y x M x A x D x T	10	0.2356	1.5467	0.1287
Within cell error	144	0.1523		

** Highly significant ($P < 0.001$).
* Significant ($P < 0.01$).

During May smelt larvae were more abundant in the shallow area (beach-3 m) than in deeper water (6-15 m) (Figs. 28-37). Mean densities in the beach to 3-m zone ranged from 1 to 213 larvae/1000 m³ during May 1978, 1979 and 1980. High abundance of smelt larvae in shallow water during May was also observed in eastern Lake Michigan near the Palisades Power Plant (WAPORA 1979) and near Ludington (Liston et al. 1981). Rainbow smelt are known to spawn in shallow water (Daly and Wiegert 1958; Rupp 1959; Jude et al. 1979b) and some

spawning takes place sooner at 1 to 3 m than at 6 to 15 m. Most larvae we collected during May probably hatched in the shallow area (beach-3 m) although some hatching may have started in deep water (6-15 m) by the May sampling period. Newly hatched larvae collected at 12 and 15 m (Figs. 30, 33, 36) may have hatched at these depths or may be carried from shallow areas by offshore currents. During 14-16 May 1979 on the south transect, smelt larvae were relatively abundant at 12 and 15 m and were scarce at the beach to 3 m, probably because most larvae that hatched in the shallows were dispersed to deeper water at sampling time (Figs. 31-33). Alongshore current (either north or south) which occurs frequently in the vicinity of the J. H. Campbell Plant at speeds varying from 0 to 30 cm/s (Liston and Tack 1976), also contributed to the quick dispersal of newly hatched smelt larvae.

Mean densities of smelt larvae in the study area during May were 15, 31 and 49 larvae/1000 m^3 in 1978, 1979 and 1980 respectively. During 1978-1980 smelt larvae were generally more abundant during May than other sampling periods (Figs. 28-37). Weekly entrainment sampling performed during 1978 and 1979 (Jude et al. 1979a, 1980) revealed that peak smelt hatching in the study area occurred during late May. In eastern Lake Michigan near Ludington, Michigan, Liston et al. (1980) observed highest density of smelt larvae at the end of May in 1978.

June--Smelt larvae were scarce during early June. No smelt larvae were collected during 1-2 June 1977. Mean larval density during early June (1978-1980) ranged from 0 to 10 larvae/1000 m^3 (Figs. 28-36). Scarcity of smelt larvae during early June was due to low hatching intensity during this period and dispersal of larvae hatched in May to deeper water. Smelt larvae collected were 5 to 15 mm, 4.1 to 14 mm and 4.1 to 13 mm during 5-10 June 1978, 4-6 June 1979 and 2-4 June 1980 respectively. The cohort that hatched in May was approximately 8 to 15 mm and made up the major portion of smelt larvae collected during early June 1978 and 1979, while newly hatched larvae 5 to 7.5 mm predominated during early June 1980 (Figs. 28-36). Reasons for this change in size composition are not known. As was found during May, no difference in size of larvae collected between shallow and deep water was observed.

Smelt larvae abundance was generally higher during late June than early June, in particular during 1979 and 1980 (Fig 37). Mean density of smelt larvae in the study area during late June was 4, 44 and 19 larvae/1000 m^3 during 1978, 1979 and 1980 respectively (Table 27). In 1978 and 1980, increase in larval density during late June resulted in part from catches of higher numbers of larvae 5-7.5 mm (Figs. 27-36) suggesting that substantial hatching took place between the early and late June sampling periods. During 1979 the increased density was due mainly to capture of a larger number of larvae 10 to 20 mm. Smelt larvae collected during late June 1980, however, included mostly recently hatched larvae 5 to 8 mm (Figs. 34-36). Reasons for the scarcity of larvae larger than 8 mm during late June 1980 are not known. In 1978, both recently hatched larvae (5-7.5 mm) and larger larvae (8-15 mm) were scarce during late June (Figs. 27-30). Variability of abundance of smelt

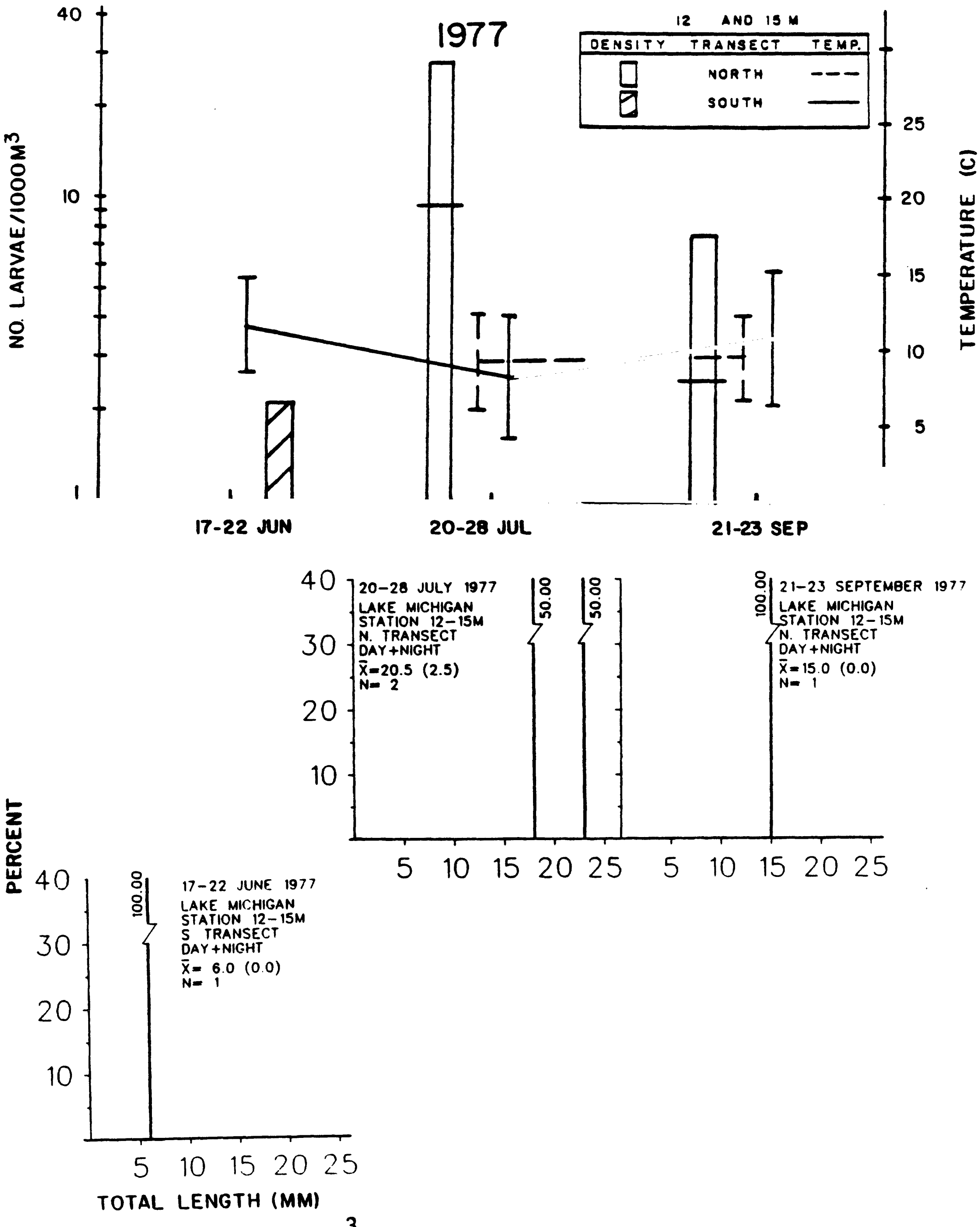


Fig. 27. Density (no./1000 M^3 plotted on log scale) of larval rainbow smelt collected during June to September 1977 at 12 and 15 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

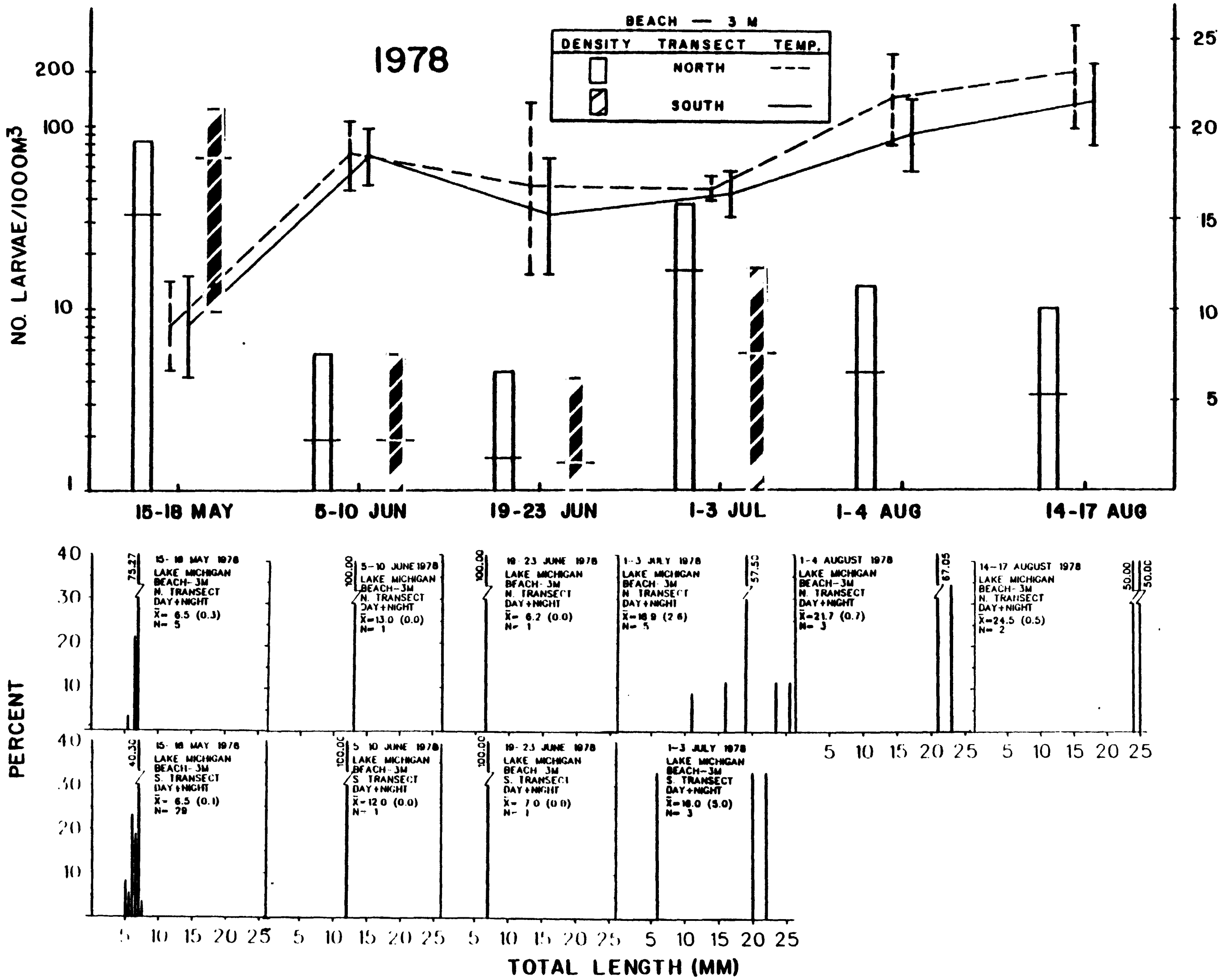


Fig. 28. Density (no./1000 M^3 plotted on log scale) of larval rainbow smelt collected during April to September 1978 at beach - 3 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

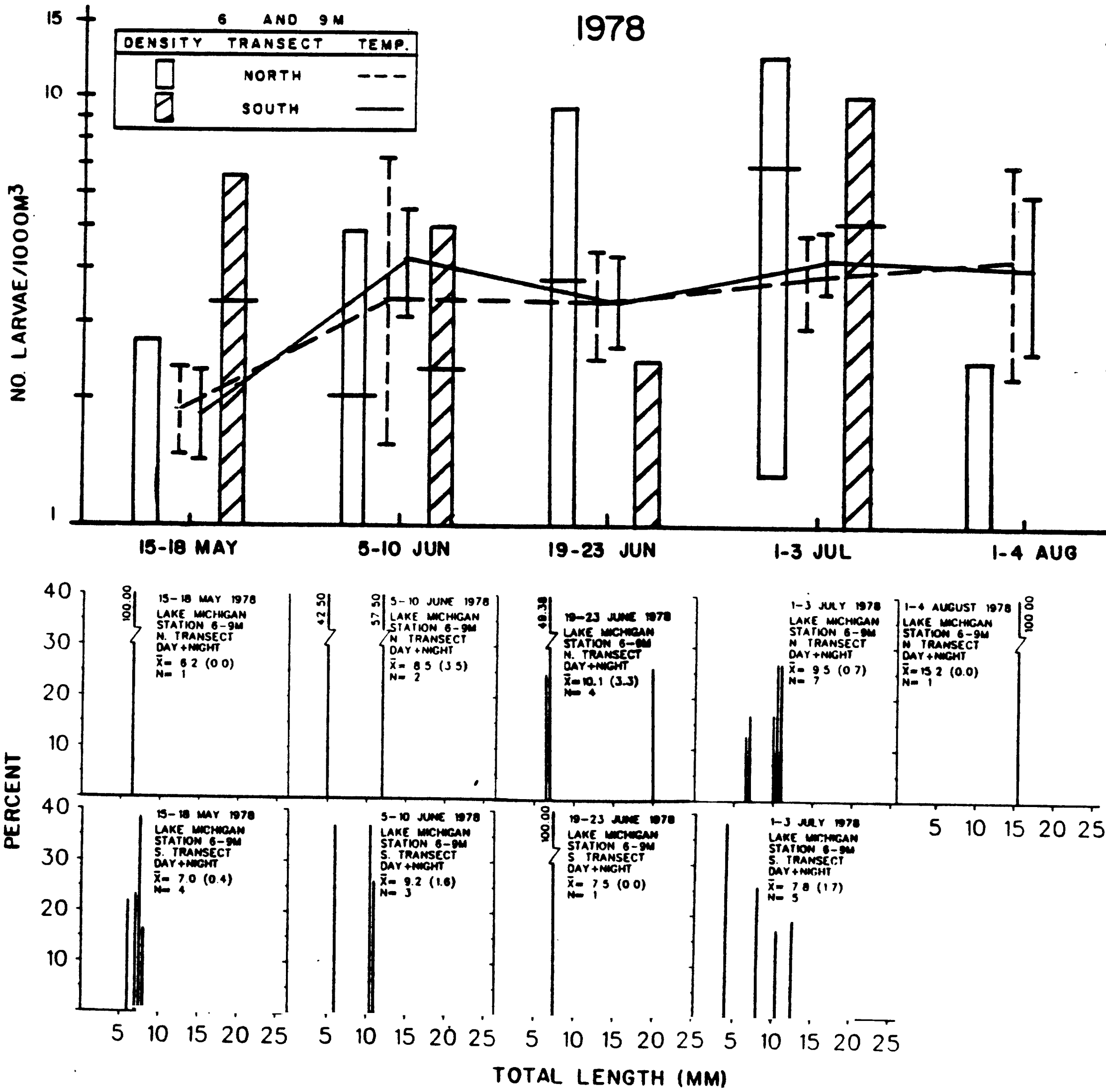


Fig. 29. Density (no./1000 M^3 plotted on log scale) of larval rainbow smelt collected during April to September 1978 at 6 and 9 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

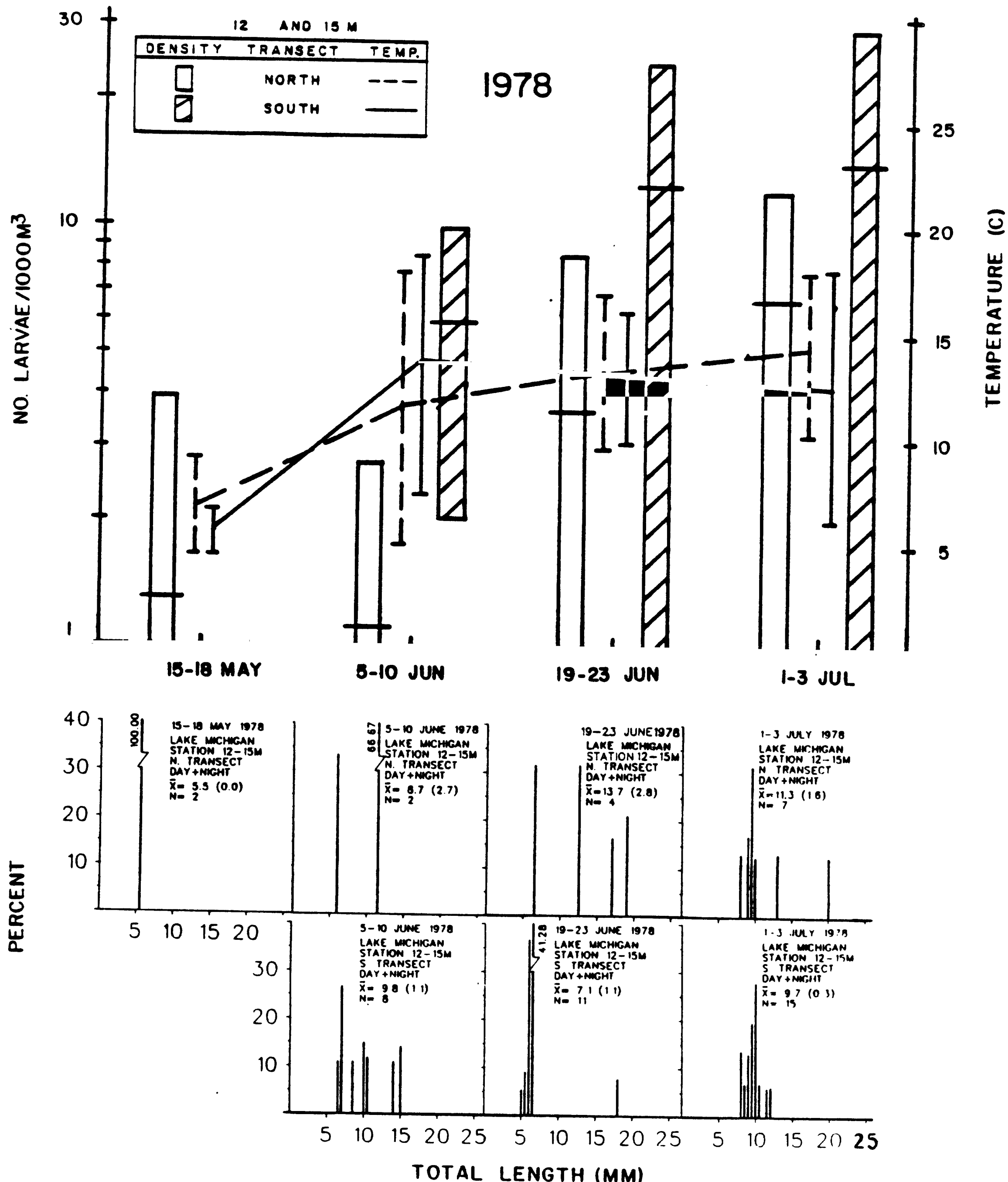


Fig. 3C. Density (no./1000 M^3 plotted on log scale) of larval rainbow smelt collected during April to September 1978 at 12 and 15 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

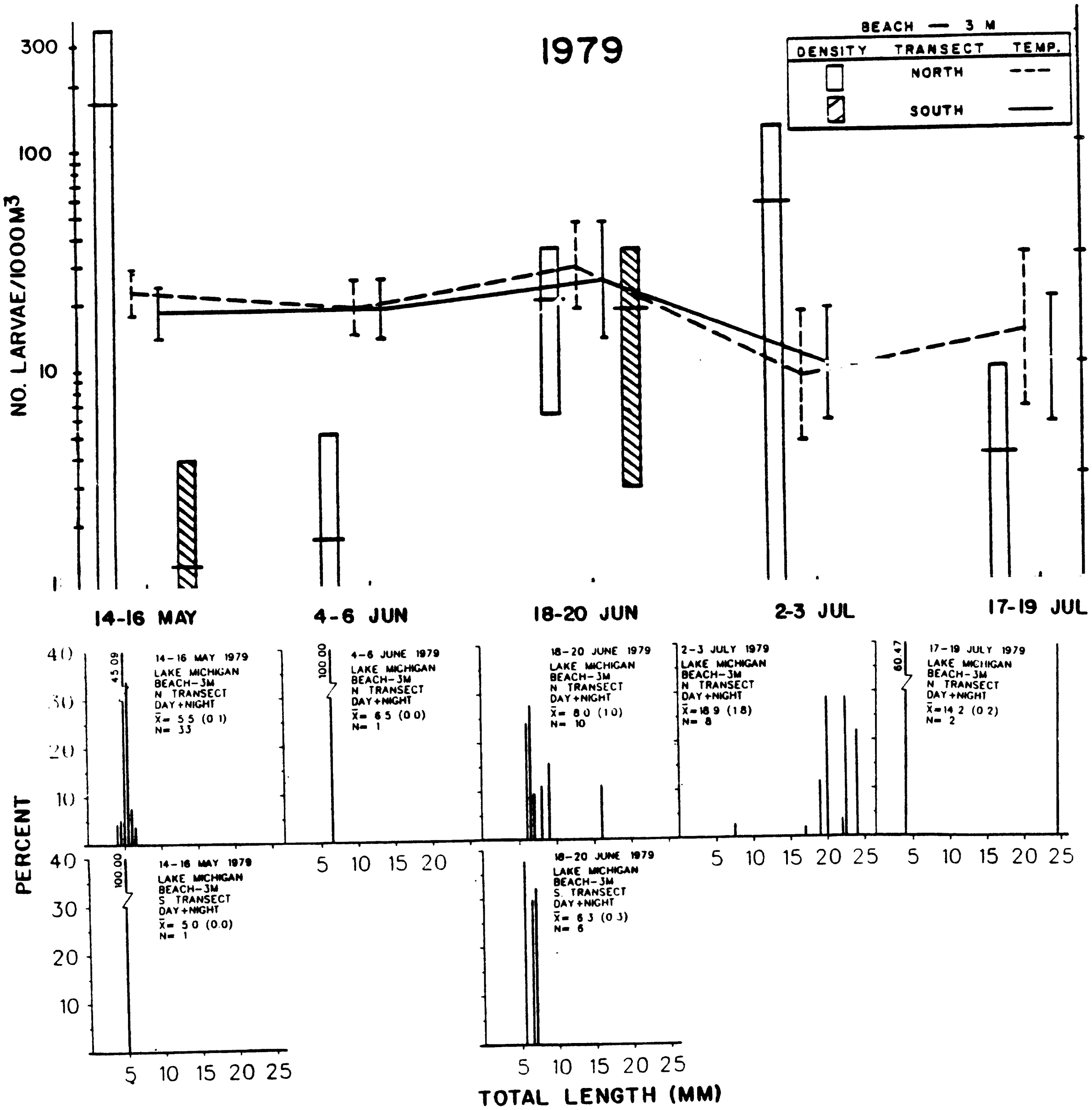


Fig. 31. Density (no./1000 M^3 plotted on log scale) of larval rainbow smelt collected during April to September 1979 at beach - 3 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

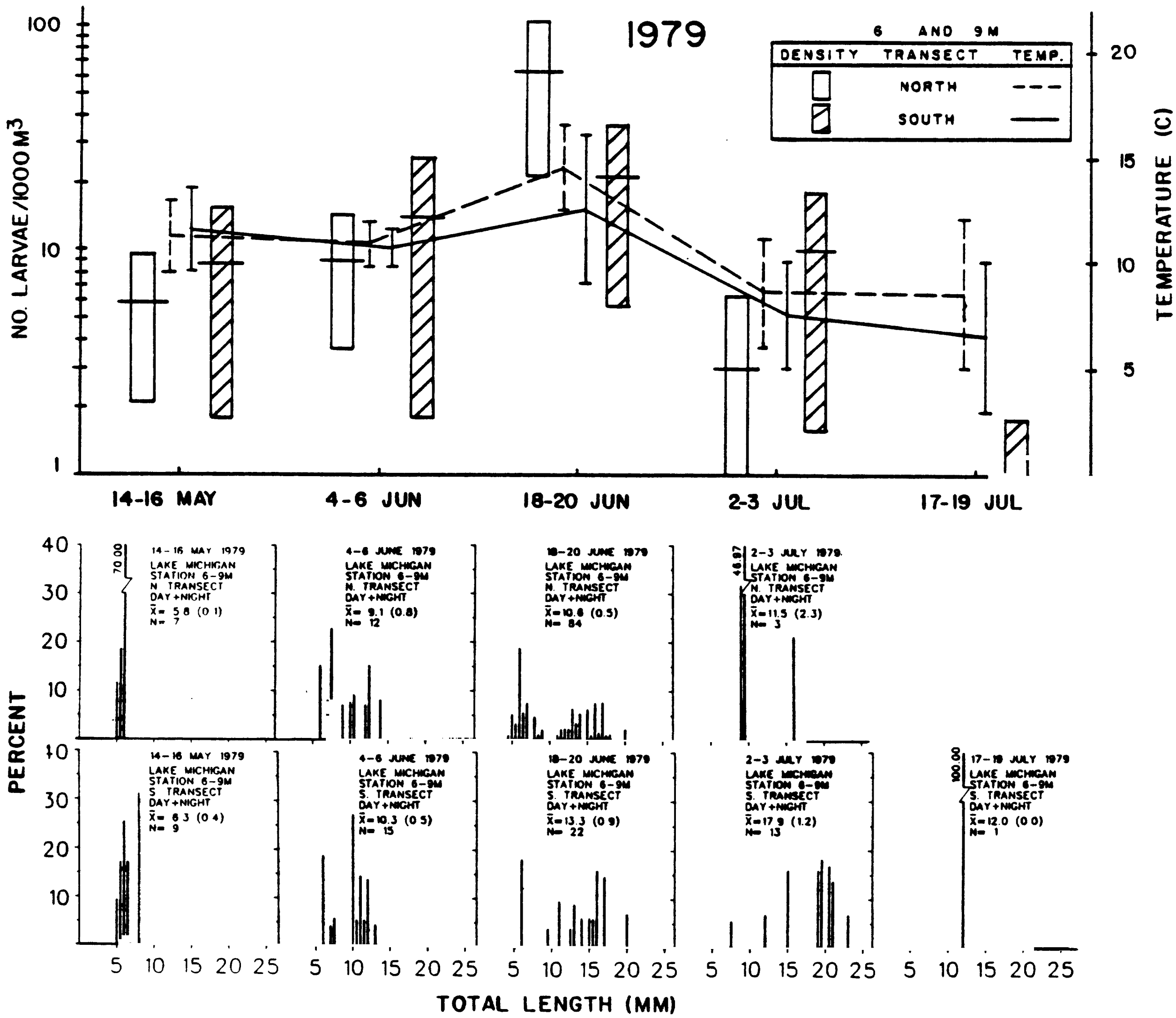


Fig. 32. Density (no./1000 M^3 plotted on log scale) of larval rainbow smelt collected during April to September 1979 at 6 and 9 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

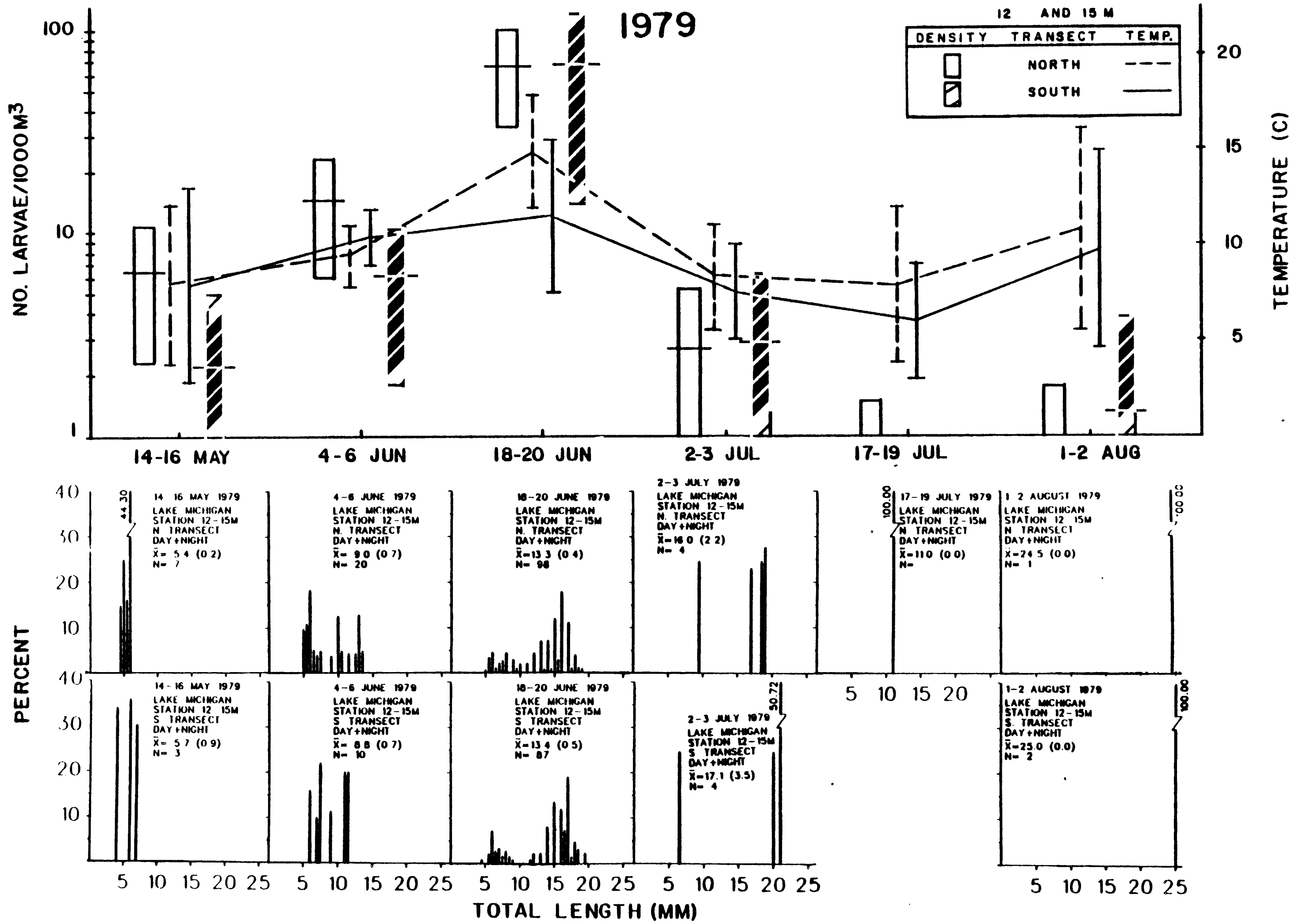


Fig. 33. Density (no./1000 M^3 plotted on log scale) of larval rainbow smelt collected during April to September 1979 at 12 and 15 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

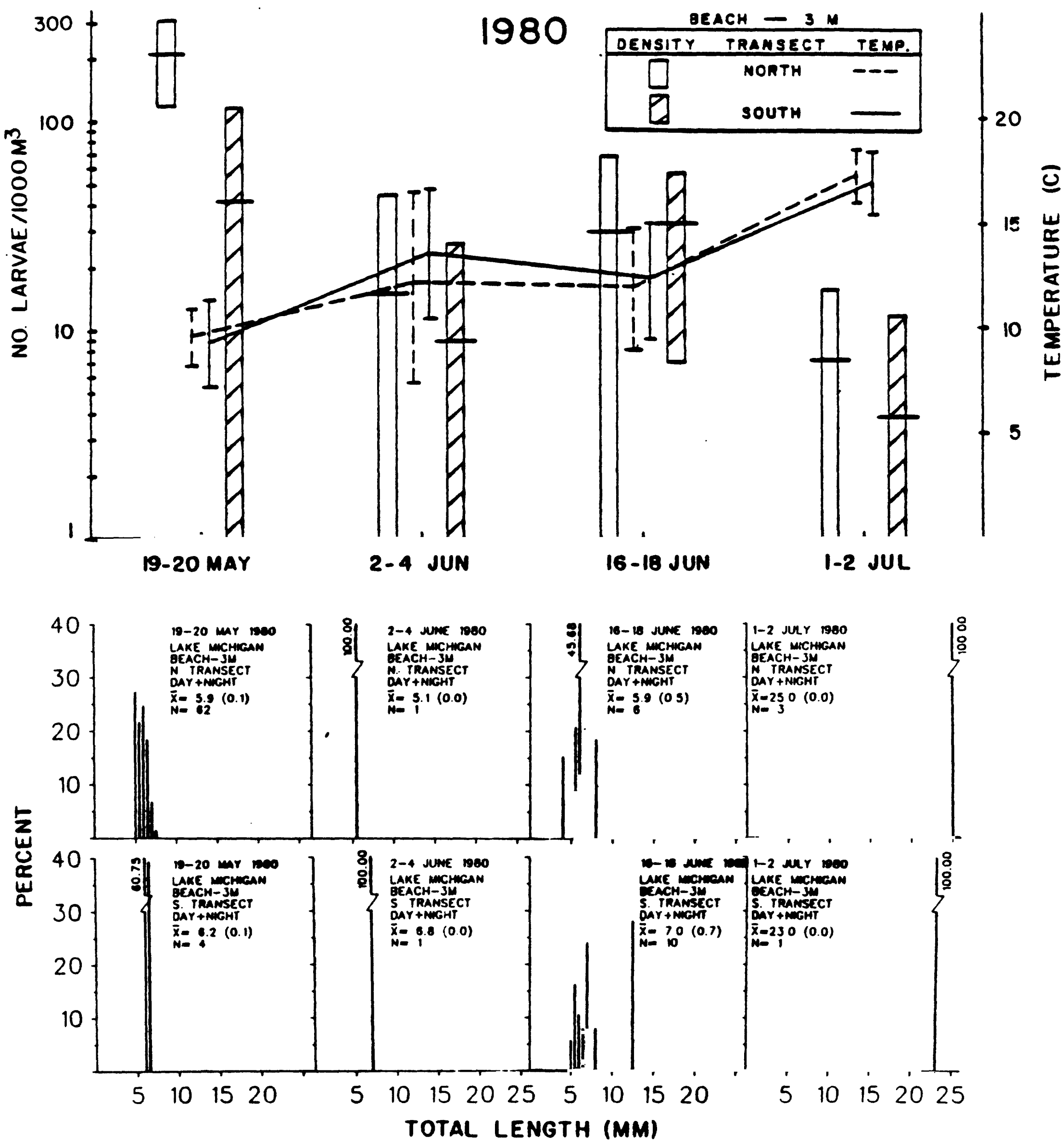


Fig. 34. Density (no./1000 M^3 plotted on log scale) of larval rainbow smelt collected during April to September 1980 at beach - 3 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

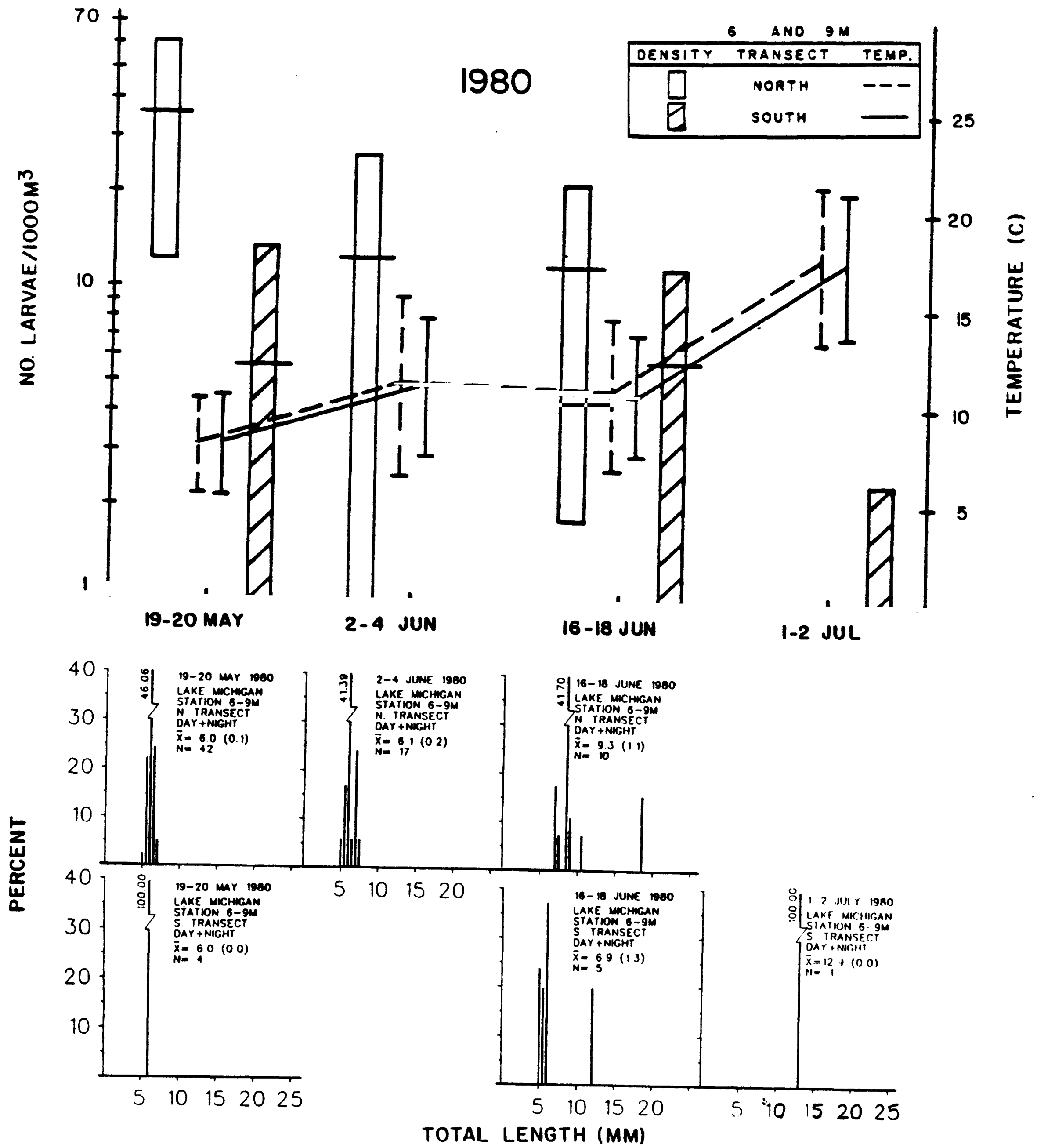


Fig. 35. Density (no./1000 M^3 plotted on log scale) of larval rainbow smelt collected during April to September 1980 at 6 and 9 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

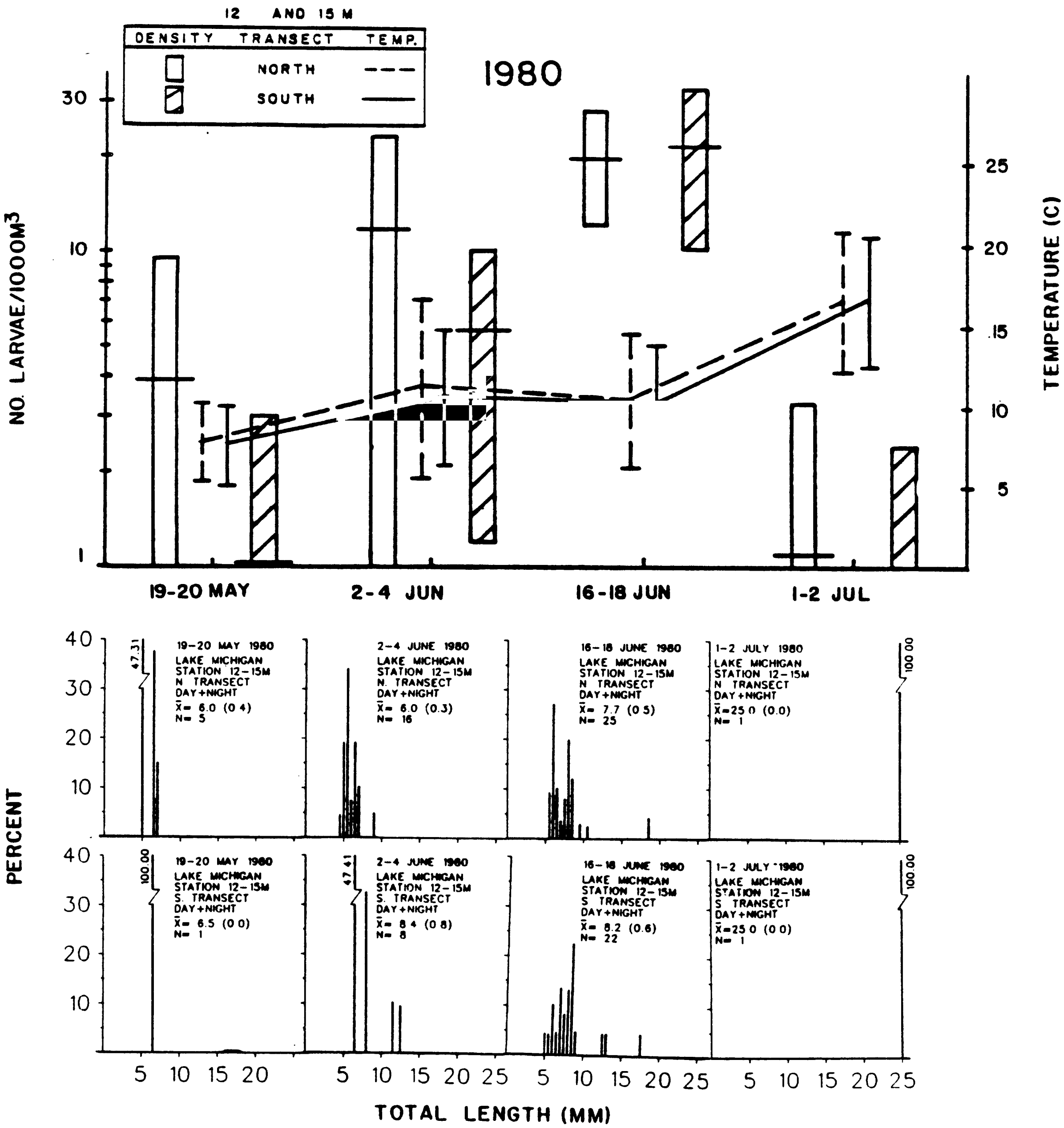


Fig. 36. Density (no./1000 M^3 plotted on log scale) of larval rainbow smelt collected during April to September 1980 at 12 and 15 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

1978

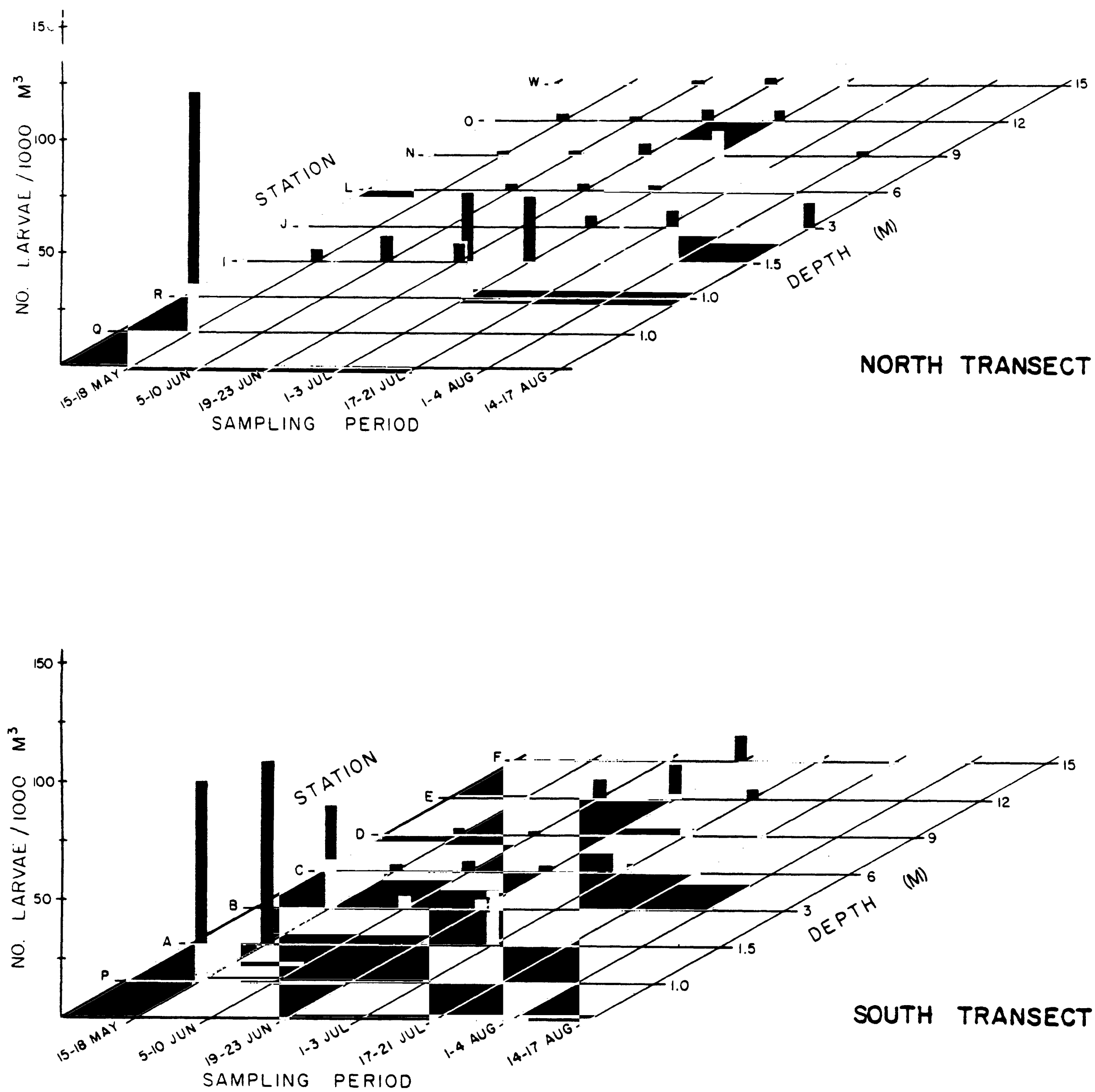
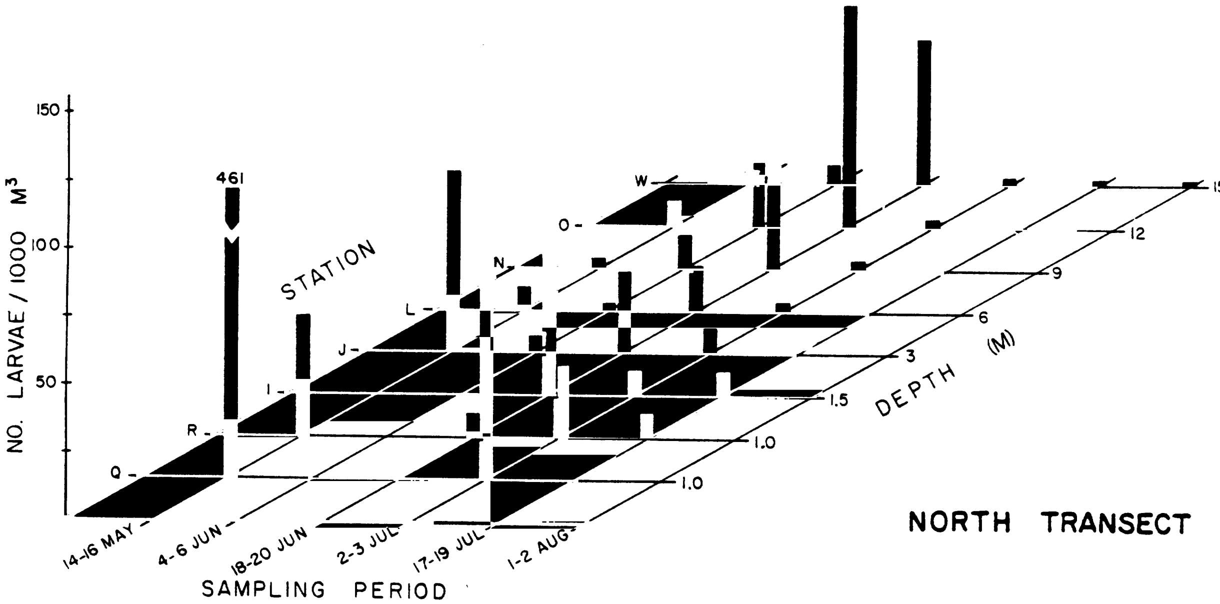


Fig. 37. Mean density (no./1000 m^3) of larval rainbow smelt for north and south transect stations in Lake Michigan near the J. H. Campbell Plant, 1978 to 1980. Mean densities were calculated by averaging densities over all gear (plankton nets and sleds), strata and diel periods (day and night) sampled.

1979



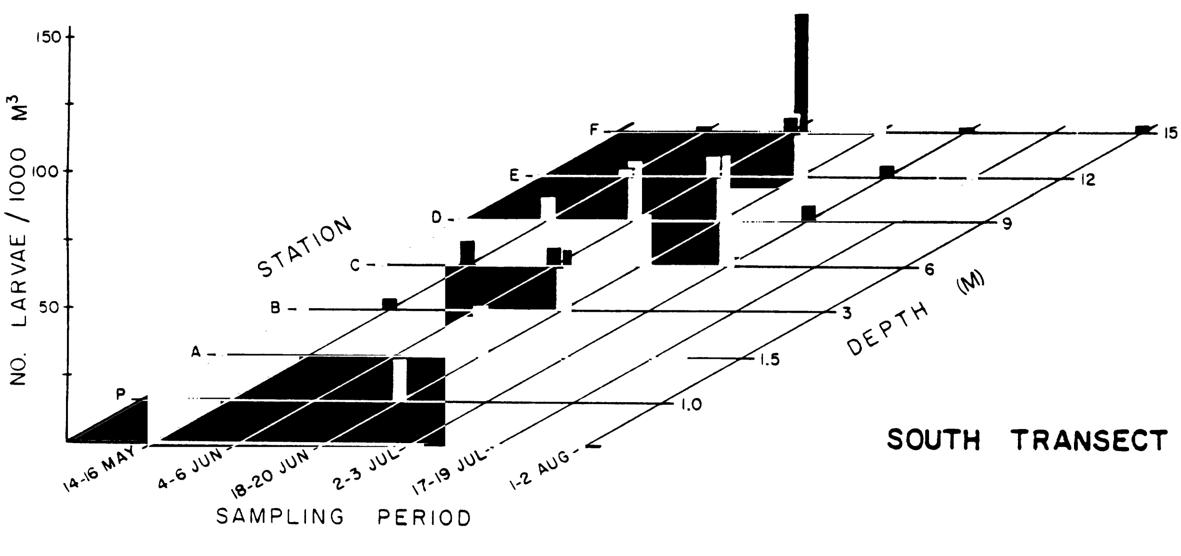
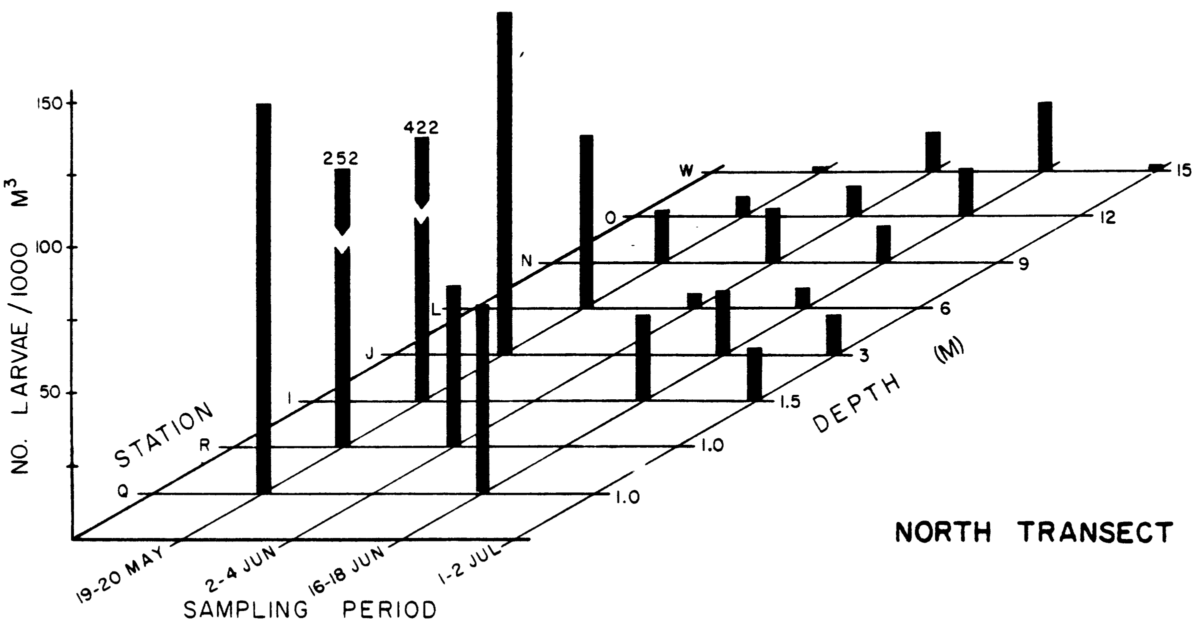


Fig. 37. Continued.

1980



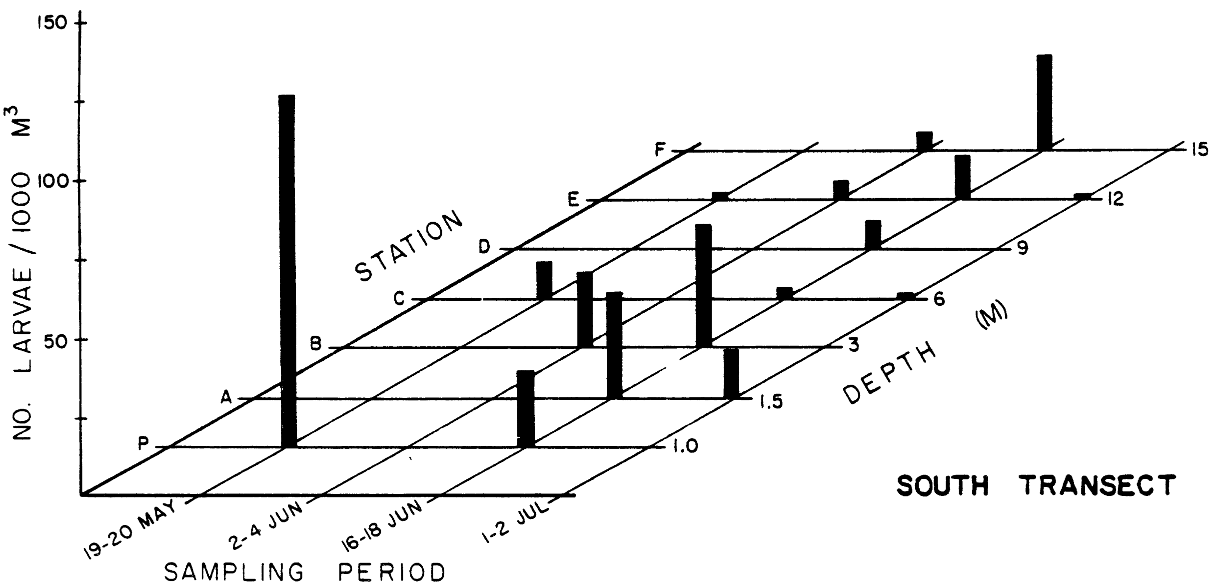


Fig. 37. Continued.

during June and the remainder of the summer during 1977-1980 may be related to water temperature. Relationships between water temperature and larval density will be discussed at the end of this section.

Table 27. Mean density of larval rainbow smelt during May-August, 1977-1980 in Lake Michigan, near the J. H. Campbell Plant, eastern Lake Michigan.

Date	Mean Density (no./1000 m^3)		
	North and South transect	North transect	South transect
1977			
17-22 June	1	0	1
20-28 July	2	2	0
1978			
15-18 May	15	11	19
5-10 June	3	2	4
19-23 June	4	3	6
1-3 July	9	10	9
1-2 August	1	2	0
1979			
14-16 May	31	56	5
4-6 June	8	9	7
18-20 June	44	50	38
2-3 July	13	20	5
17-19 July	1	1	0
1980			
19-20 May	48	83	13
2-4 June	9	13	5
16-18 June	19	23	14
1-2 July	2	3	2

During late June smelt larvae were generally more abundant in deeper water than in shallow areas (Fig. 37). Mean density ranged from 1 to 32 larvae/1000 m^3 from the beach to 3 m, 1 to 63 larvae/1000 m^3 at 6 and 9 m and

4 to 67 larvae/1000 m^3 at 12 and 15 m (Figs. 27-36). As has been observed during previous sampling periods there was little difference in size between larvae caught in shallow and deeper water.

Three size groups of rainbow smelt larvae were observed during late June. The first group included recently hatched larvae 4.5-7.5 mm which were most abundant during 18-20 June 1979 and 16-18 June 1980. During late June newly hatched larvae appeared to be more widely dispersed in the study area than during May. Because of relatively warm water at beach to 3-m stations in spring (Appendixes 5 and 6), smelt eggs laid in the shallow area during April and May probably hatched by early June. Since no smelt spawning has been observed in the shallow area during June, newly hatched larvae collected during late June and July (Figs. 27-36) probably originated from hatching in deep water (6-15 m). Delay of hatching of smelt eggs deposited in deep water until late June or July was probably caused by low water temperature. Bottom temperatures at 6 to 15 m near the Campbell Plant ranged from 5.2 to 9.2 C during 19-20 May 1980 and 6.4 to 14.6 C during 1-2 June 1980. The second size group of larvae collected during late June was comprised of larvae 8-12 mm. Larvae in this size range were scarce during 19-23 June 1978 and 18-20 June 1979 but were relatively common during late June 1980 (Figs. 27-36). Based on the observed growth rate of the first cohort collected during the first few weeks of life, larvae 8-12 mm collected during late June probably hatched around early June. Larger larvae 12.5-20 mm were undoubtedly members of the first cohort which hatched during May and were approximately 1-mo old by late June. Mean lengths of this cohort during late June 1978, 1979 and 1980 were 17.5, 15.7 and 16.0 mm respectively. Bigelow and Schroeder (1963) reported a slightly larger size (17 to 18 mm) for 1-mo-old smelt larvae in the Atlantic coastal drainage. Members of the first cohort were the most abundant size group during 18-20 June 1979. They were scarce during late June in 1977, 1978 and 1980. Based on larval density observed during May (Table 27) smelt larvae in the first 1980 cohort were relatively abundant. The reason for the low catches of larvae in this cohort during late June 1980 was probably their widespread distribution.

July--Mean density of smelt larvae during early July declined substantially from levels observed during late June (Table 27). This decline was probably due to dispersal of smelt larvae hatched during May and June and scarcity of newly hatched larvae during early July. During 1978, however, mean density of smelt larvae during 1-3 July was higher than that observed during 19-23 June. Reasons for this increase are not known. During early July larval densities in shallow and deep water were in general similar (Figs. 28-36).

Rainbow smelt larvae collected during early July ranged from 4.1 to 24 mm and may be subdivided into three size groups. Few newly hatched larvae 4.1-7.5 mm were found in 1978 and 1979. The second group consisted of larvae 8-17 mm which probably hatched from early to late June. Larvae in this size range were more common during 1-3 July 1978 than the early July sampling period in 1977, 1979 and 1980. The third group was comprised of larvae 18-25 mm which were members of the cohort that hatched during May. The latter size group occurred most commonly during 1-3 July 1979.

Small numbers of YOY smelt 26-28.5 mm, which were undoubtedly members of the first cohort, were caught in plankton nets and sleds during 1-2 July 1980 (Appendix 11). YOY smelt > 25.4 mm were not caught during early July larvae sampling in 1977, 1978 and 1979.

Smelt larvae were relatively scarce during late July (Fig. 37). They were caught in low numbers during 19-23 July 1977 and 17-19 July 1979 (Figs. 27, 31-33). None were found during late July 1978 and 1980. As was found during June and early July, smelt larvae were widely dispersed in the study area during late July. Smelt larvae collected during late July ranged from 12 to 25 mm (Figs. 27, 31-33). A newly hatched larva 4.1 mm TL was also observed during 17-19 July 1979.

Smelt fry 27-40 mm were commonly caught in plankton nets and sleds during late July from 1977 to 1980 (Appendixes 11, 39, 40 and 41). Smelt fry were found in shallow and deep water at both transects. They were undoubtedly members of the cohort that hatched during May and were approximately 2-mo old by late July. Size range of fry collected during late July was comparable to lengths of 27-34 mm reported for 2-mo-old smelt YOY (Bigelow and Schroeder 1963).

August and September--Smelt larvae were scarce during August. A few larvae 15-25 mm were caught during early and late August 1978 and early August 1979. Smelt larvae have never been caught during September, except for a 15-mm larva collected during 21-23 September 1977 (Fig. 27). Smelt fry 26-45 mm continued to increase in density in our study area during early August and reached a peak during late August. Smelt fry occurred from 1 to 15 m. High abundance of smelt fry was commonly observed in plankton nets and sleds towed at 1.5 and 3 m (Appendixes 10, 39, 40 and 41). These data suggested that YOY smelt, which were widely dispersed from May to July, began to congregate inside the 15-m contour during August. In eastern Lake Michigan, near Ludington, most YOY smelt collected in nets during August occurred at 1.5 and 3 m (Liston et al. 1981). During September smelt fry were scarce in plankton nets and larval sleds (Appendix 11).

During June and July distribution of smelt larvae appeared to be related to water temperature. Smelt larvae tended to be most common at moderately high temperatures. High catches of smelt larvae were observed during late June 1979 and late June 1980 at water temperatures of 13 to 15 C (Figs. 22, 31-36). These data agreed with Jude et al. (1979b) who found most YOY smelt in water temperatures of 13-14 C. Smelt larvae appeared to avoid high temperatures (16-24 C) which were observed during June 1978 and early July 1980. Smelt larvae were also scarce during sharp drops in temperature due to upwelling of very cold water. Only low densities of larvae were observed during early and late July 1979 when water temperatures ranged from 4 to 12 C.

Young-of-the-Year--

Seasonal distribution--

July--YOY smelt 29-40 mm first entered trawl catches during July. Catches of YOY during July were relatively low, ranging from 1 during July 1978 to 341 during July 1977. Scarcity of smelt YOY during July may be due to their widespread distribution in the inshore area as has been observed during fish larvae sampling. In addition, YOY smelt generally live in the upper levels of the water column until late summer (Wells 1968) and were therefore only partially vulnerable to bottom trawls during July. During July, YOY were found mostly at 6 and 9 m; a few YOY also occurred at beach, 3, 12 and 15 m (Fig. 38).

August--During the 4-yr period catches of YOY smelt 26-54 mm peaked in August. In southeastern Lake Michigan high catches of YOY were also observed during August (Jude et al. 1979b). As has been found during fish larvae sampling, YOY smelt began to concentrate in the inshore area during August. Crestin (1973) reported YOY migrate to the bottom as they grow older. In eastern Lake Michigan YOY smelt move to the bottom by late summer or during the fall (Wells 1968). High catches of YOY smelt in bottom trawls during August indicated that migration to the bottom started during this month in the vicinity of the Campbell Plant.

Small numbers of YOY smelt occurred in beach seines during August (Appendixes 8, 31-32). August trawl catches showed that YOY were less abundant at 3 m than at deeper water stations (Fig. 38). Mean catches of YOY smelt per trawl haul at 3 m ranged from 8 to 80 during August 1977-1980. Plankton net and sled tows however, sometimes captured YOY smelt (>25.4 mm) in relatively high densities at 1.5 and 3 m. During August 1977 and 1979 YOY smelt were most abundant at 12 and 15 m (Fig. 38). Mean catches per trawl haul at these depths were 512 and 1250 YOY during August 1977 and August 1979 respectively. During August 1978 and 1980 YOY were most common at 6 and 9 m. Mean catches at 6 and 9 m during these two sampling periods were 437 and 1750 YOY per trawl haul respectively.

Abundance of YOY smelt in the study area may be in part related to water temperature. Low catches of YOY in the shallow water may be due to relatively high temperatures (15.8-25.7 C) observed from the beach to 3 m during August trawling (Appendixes 4, 18-20). YOY smelt tended to occur in moderately warm water during August. Highest catches of YOY during August 1977 and 1979 occurred at mean bottom temperatures of 14.6 and 14.0 C respectively. During August 1978 and 1980 YOY were most common at mean bottom temperatures of 19.5 and 15.5 C respectively. In southeastern Lake Michigan, Jude et al. (1979b) found YOY over a wide range of temperatures (11-19 C), with highest catches observed at 13-14 C. Smelt YOY in Lake Erie were reported to inhabit the thermocline during the summer (MacCallum and Regier 1970). High catches of YOY during August 1977-1980 in the study area were also generally observed near the thermocline (Figs. 22 and 38).

During the 4-yr period YOY catches appeared to be increasing. Catches per trawl haul during August were 330, 183, 703 and 638 YOY from 1977 to 1980 respectively. YOY smelt were substantially more abundant in 1979 and 1980 than during the previous 2 yr. Discussion of the increased smelt abundance will be presented at the end of the adult section.

During August YOY smelt collected in trawls ranged from 30 to 54 mm. Kendall (1927) reported a similar size range (31-51 mm) for 3-mo-old smelt in Maine lakes. Most fish we collected ranged from 35 to 44 mm with an interval midpoint of 40 mm (Appendixes 8, 30, 31 and 32). During August 1977-1980 YOY in the 40-mm length interval made up 63 to 82% of the total YOY smelt collected. YOY < 35 mm represented 13 to 20% of the total YOY catches, while YOY > 44 mm accounted for only 0.1 to 7%.

September--Catches of YOY in September declined substantially from the levels observed during August probably as a result of YOY migration to deeper water. In Lake Erie, MacCallum and Regier (1970) found YOY smelt with yearlings and adults at 24-27 m in September. Jude et al. (1979b) also observed a YOY smelt catch decline during September in inshore southeastern Lake Michigan.

As was observed during August, YOY were scarce in shallow areas due to warm water (Fig. 22). During September 1980 appreciable numbers of YOY were collected in the beach zone because of relatively cool water (16.5 C) during sampling. During September high catches tended to occur in colder water than in August. During September 1977, 1979 and 1980, YOY were most common at 12 and 15 m at mean bottom temperatures ranging from 6.3 to 10.5 C (Fig. 22). Many YOY were also found at 6 and 9 m during September during these 3 yr because of relatively cold water (7.1-12.6 C) at these depths (Fig. 22). During September in Lake Michigan Brandt et al. (1980) found most YOY smelt at 5-6 C at night and at 13-14 C during the day. During September 1978 YOY appeared to avoid the 6- and 9-m contours because of warm water (mean bottom temperature 18.7 C). Substantial quantities of YOY were, however, collected during September 1978 at 12 and 15 m where mean bottom temperature was 16.6 C.

Catches of YOY smelt during September over the 4-yr period were less variable than was observed during August. Mean catches per trawl haul in September ranged from 78 to 126 during the 4-yr period. Differences in YOY catches may be related to water temperature. Low catches of YOY during September 1978 (78 YOY/trawl haul) resulted from water temperatures which were too high, while high catches observed during September 1977 (112 YOY/trawl haul) and 1979 (126 YOY/trawl haul) coincided with periods of cold-water upwellings (Fig. 22). During September 1980, water temperature was relatively high (16.9 C at 6 and 9 m) on the north transect and relatively low (12.1 C at 6 and 9 m) on the south transect. A mean catch of 99 YOY per trawl haul was found during the sampling period. During September YOY smelt ranged from 30 to 64 mm. As was found during August the major portion of YOY were 35-44 mm.

October, November and December--YOY smelt in appreciable numbers were caught from October to December during the 4 yr suggesting that one portion of the YOY population continued to inhabit inshore waters until the end of the

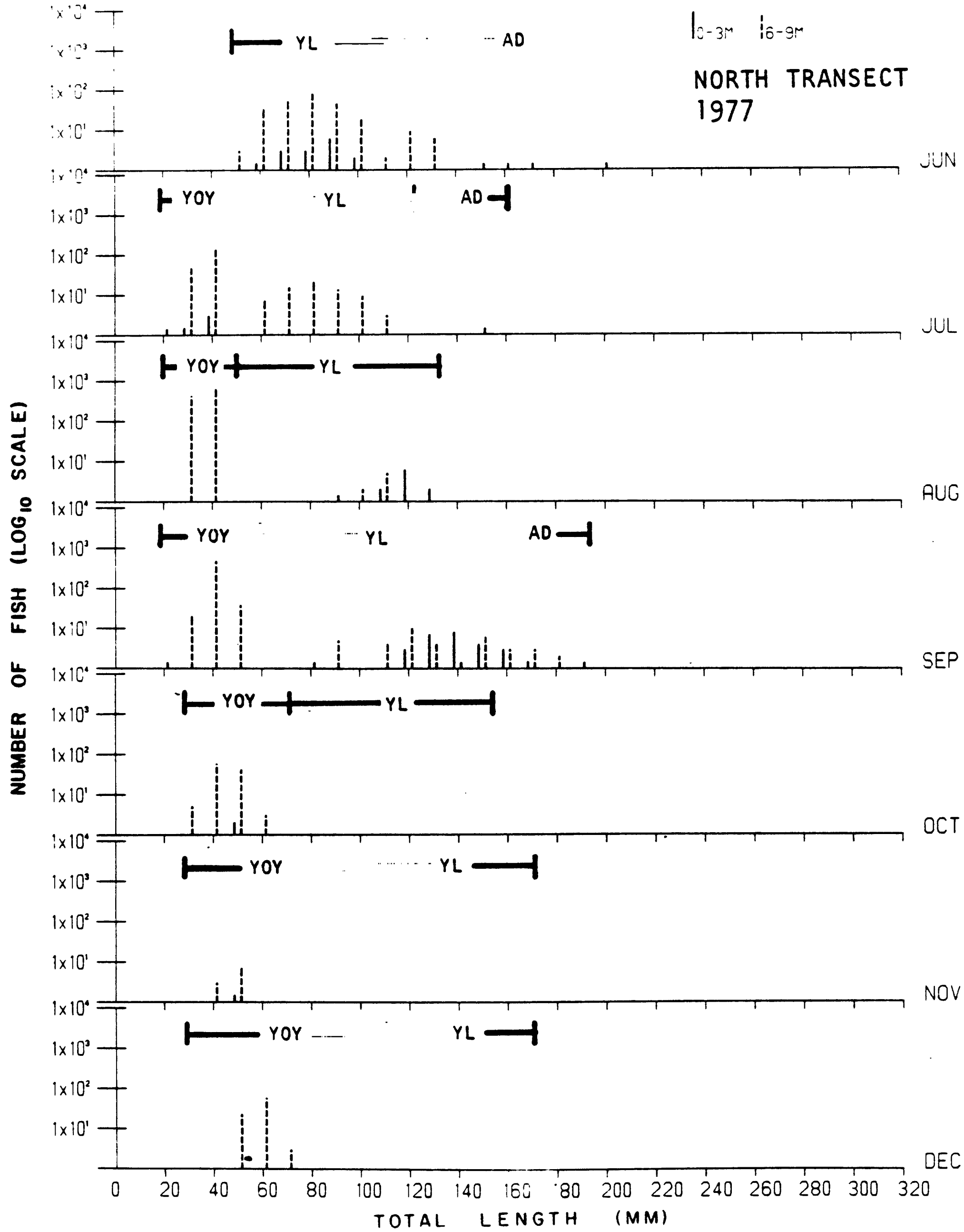
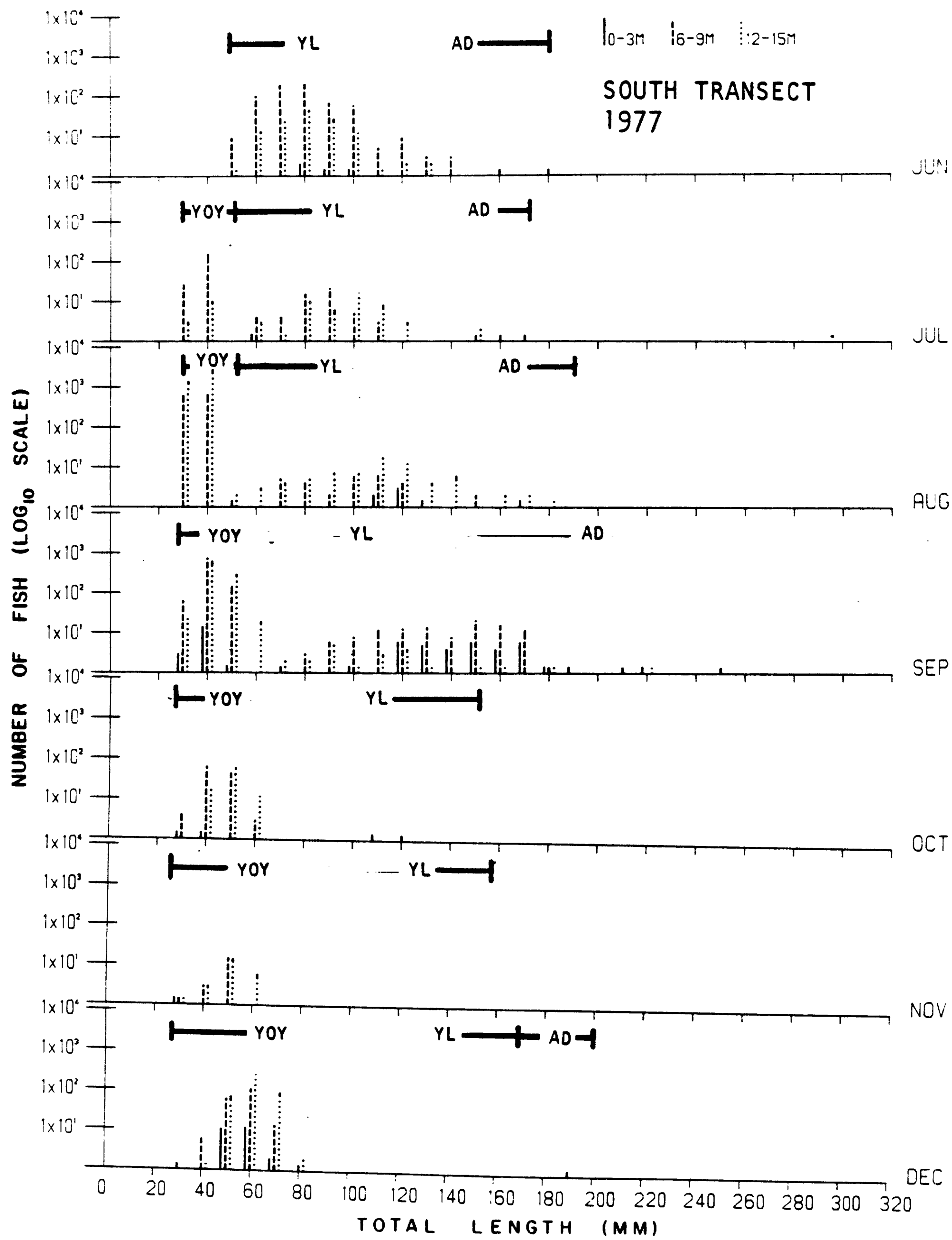


Fig. 38. Length-frequency histograms for rainbow smelt collected during June - December 1977 and April - December 1978-1980 at north and south transects. Stations were combined into two groups for the north transect: beach and 3 m; 6 and 9 m and into three groups for the south transect: beach, 1.5 and 3 m; 6 and 9 m; and 12 and 15 m. Diel periods and gear types were pooled. YOY = Young-of-the-year; YL = Yearling; AD = Adult.



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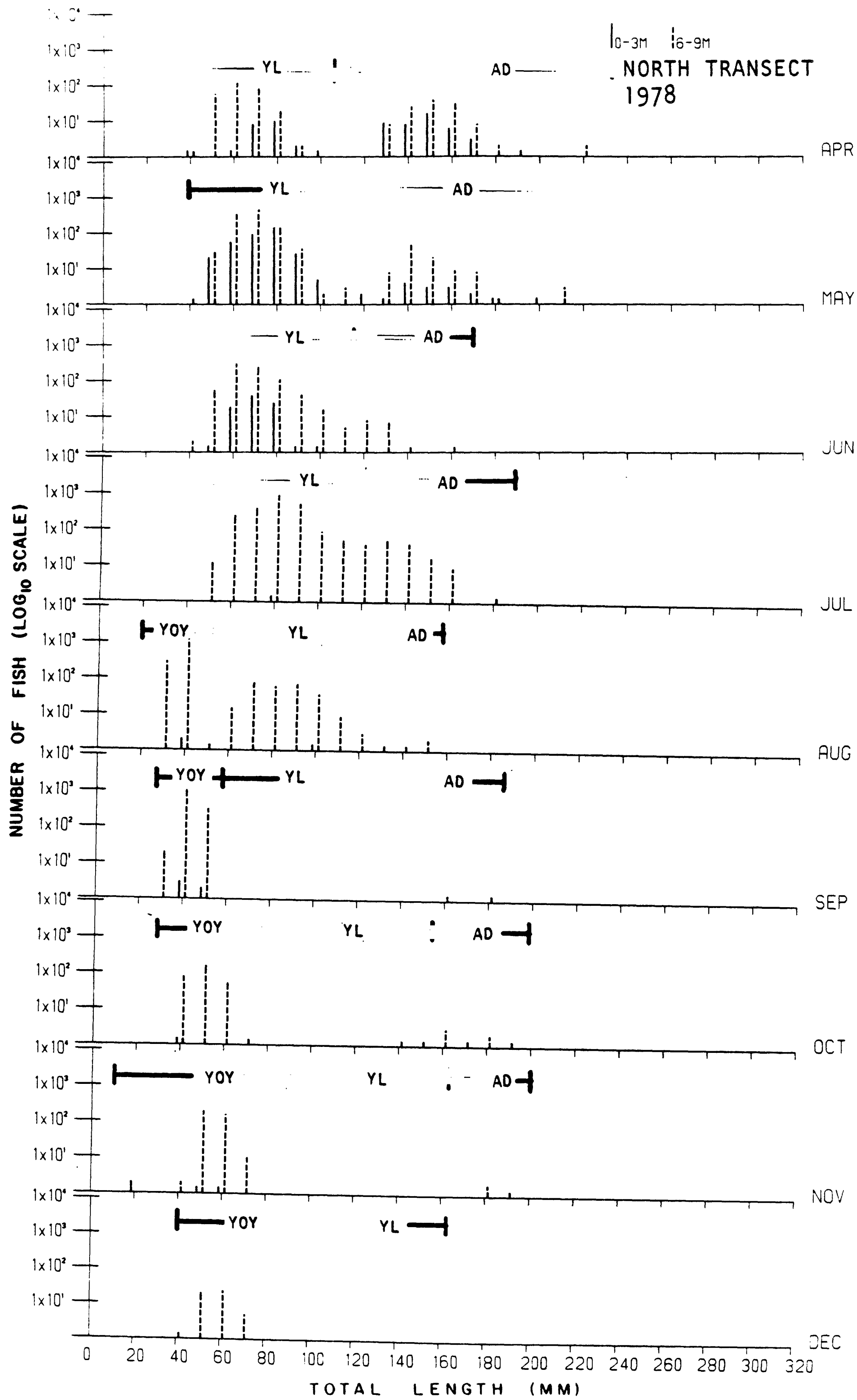

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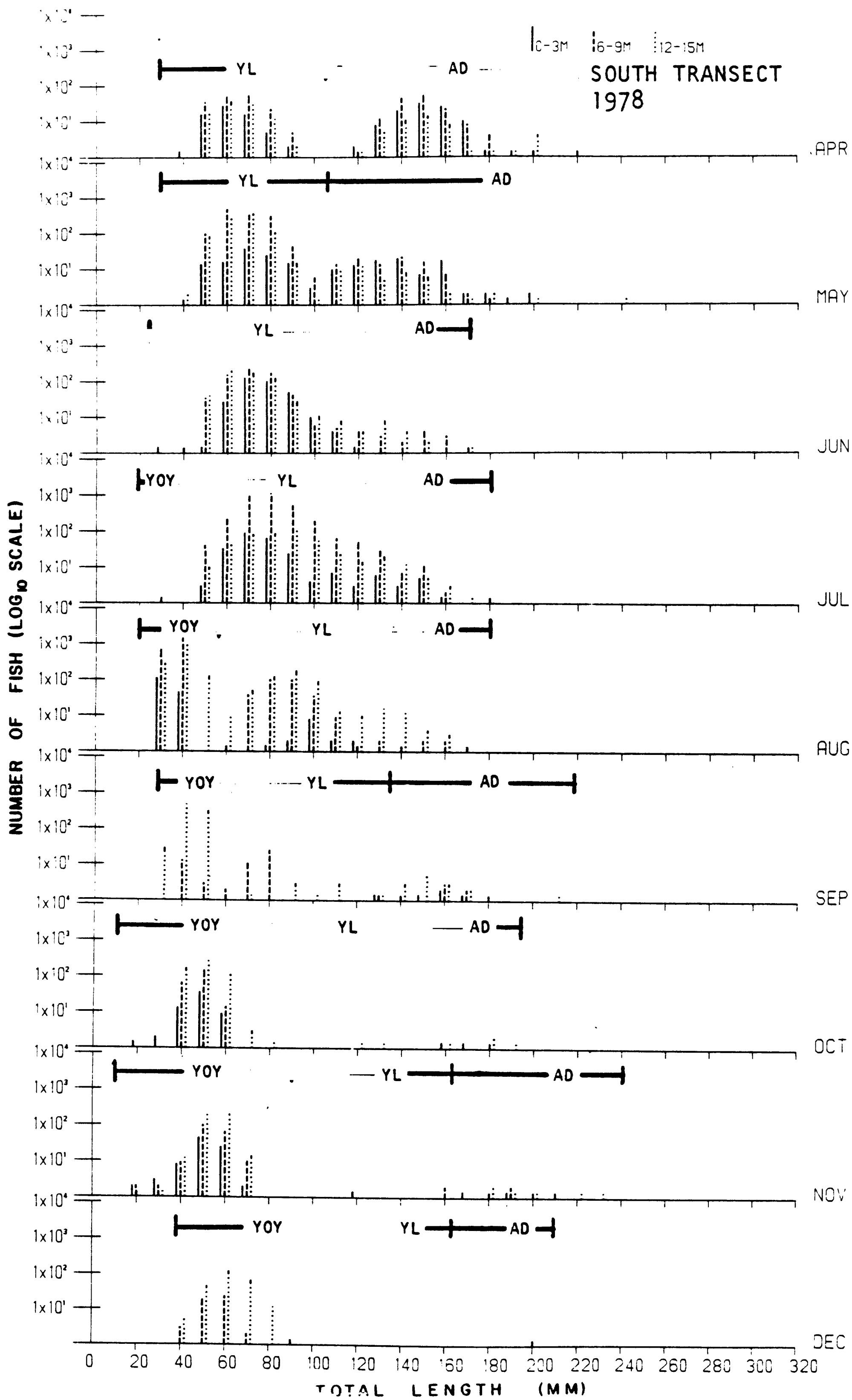

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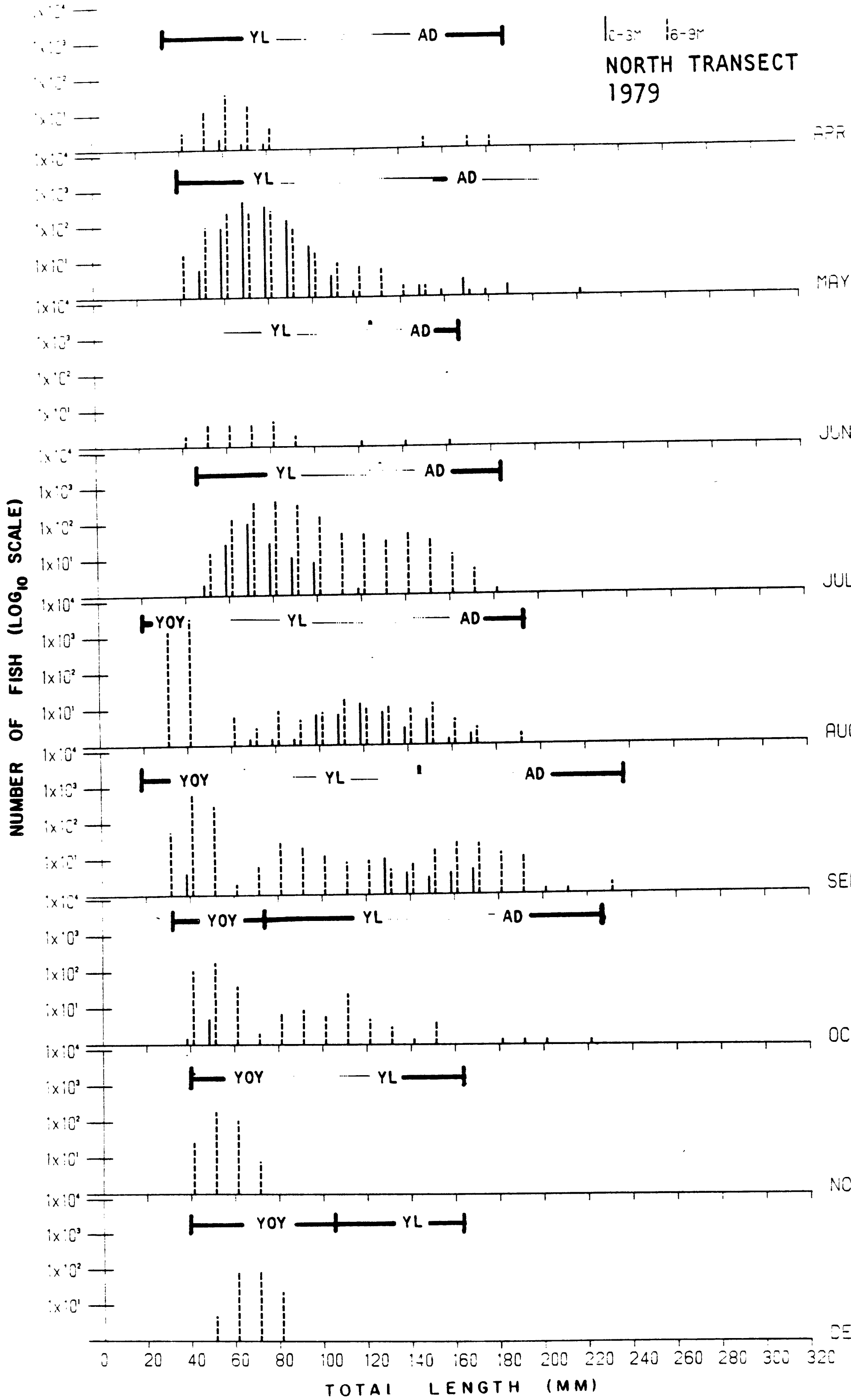

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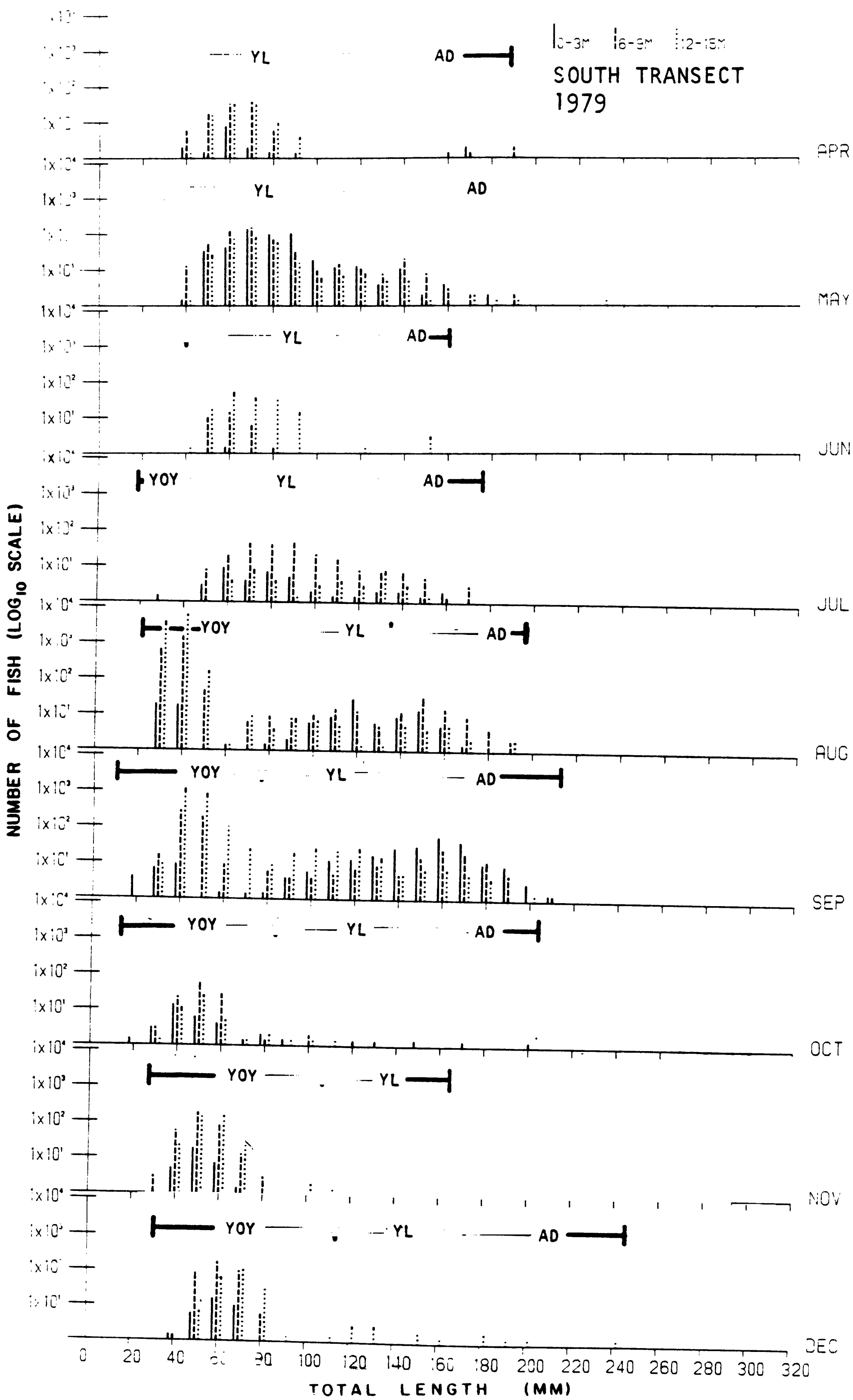

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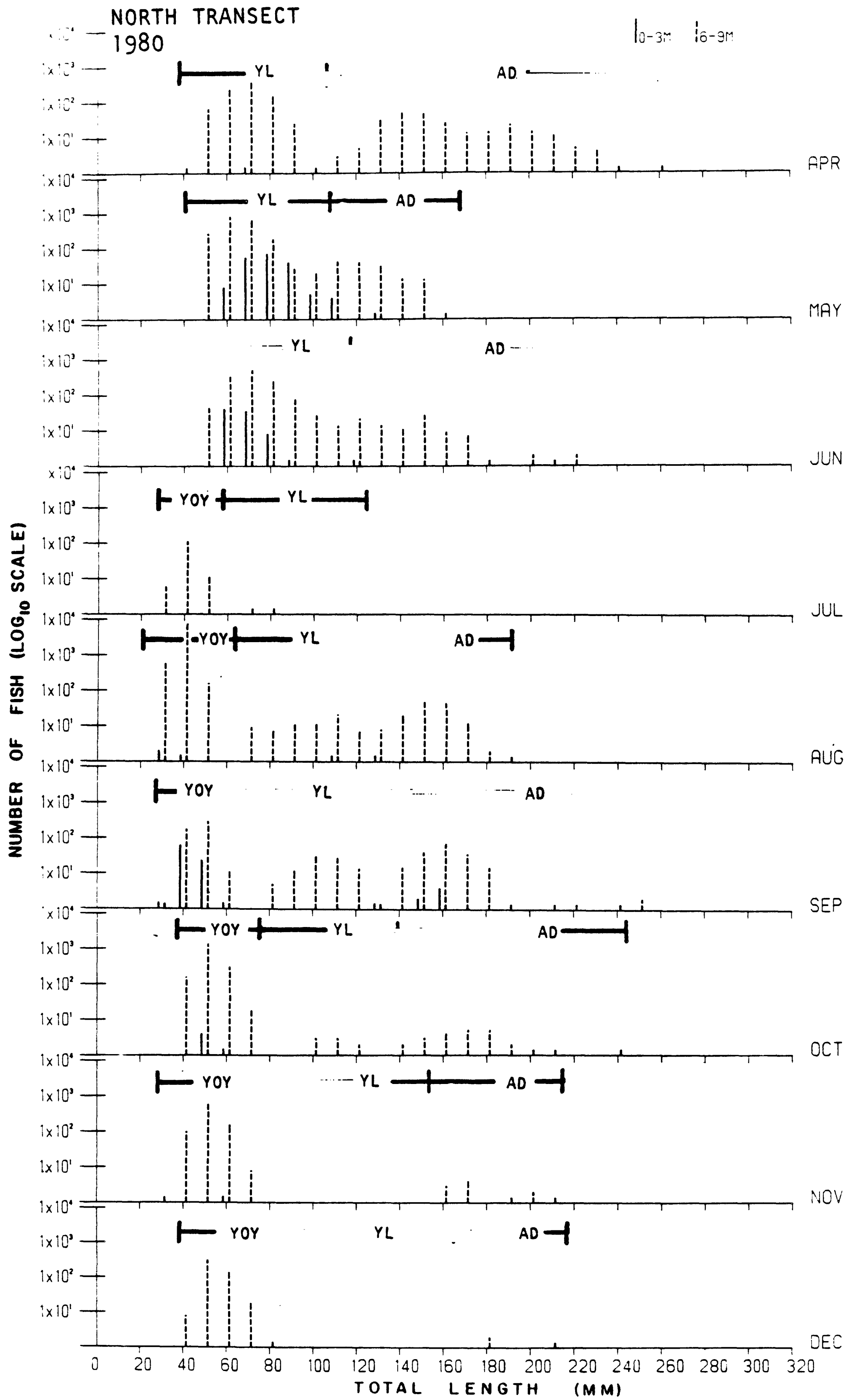

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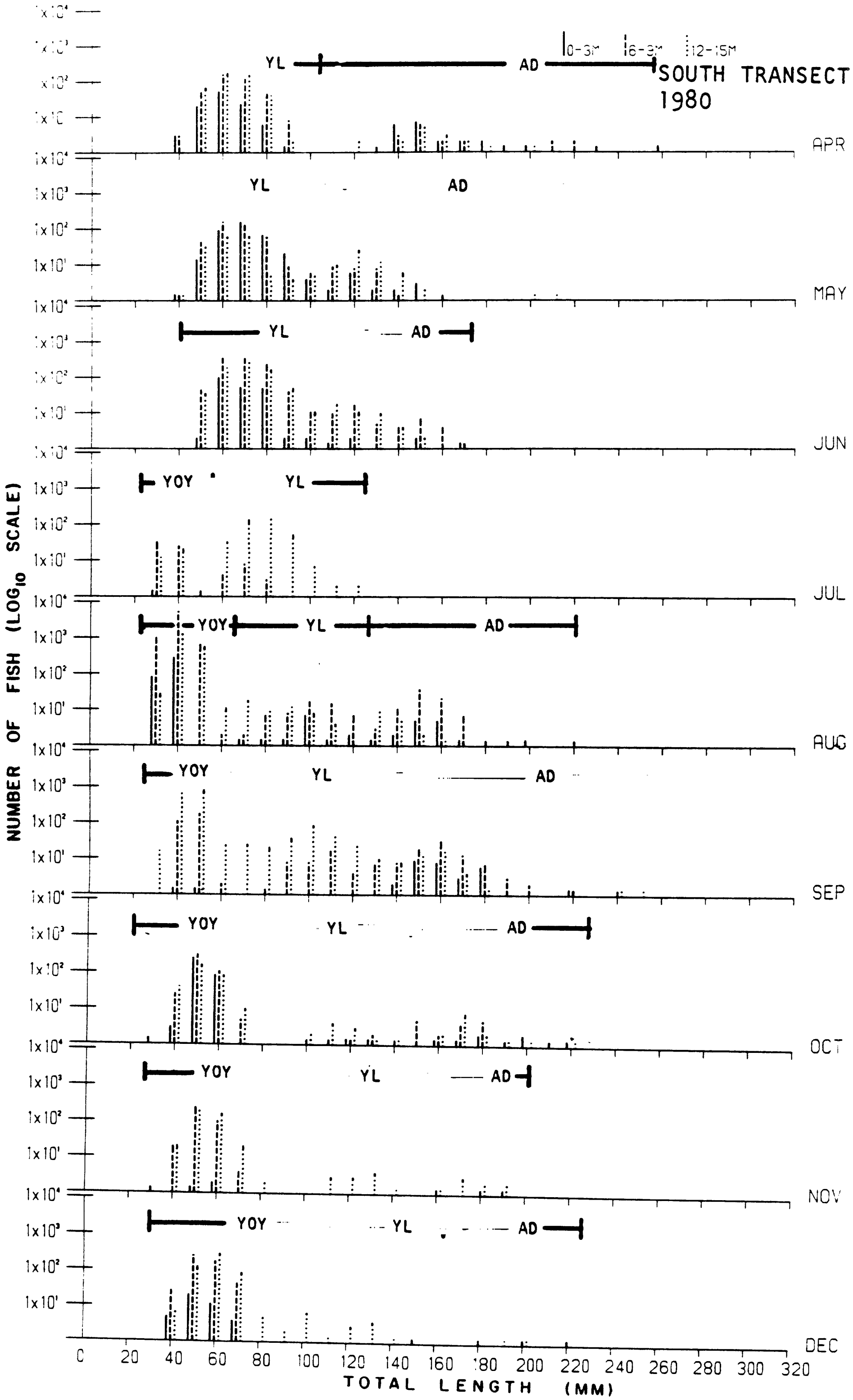


Fig. 38. Continued.

year. During fall, YOY may be found from the beach to 15 m. Only a small number of YOY occurred in the shallow area (beach-3 m), except during October 1980, when substantial numbers of YOY were caught from the beach to 3 m (Fig. 38). Most YOY were found at 6 to 15 m during fall.

Abundance of YOY smelt during fall varied considerably. Catches per trawl haul ranged from 3 to 40 YOY during October, November and December over the 4-yr period. During 1978 and 1979 highest monthly catches in the fall occurred in November in water temperatures of 6.5 to 13.2 C (Fig. 22). During fall 1980 catches of YOY were highest during October in water temperatures of 7.3-12.0 C. YOY were still common inshore during December when water temperatures ranged from 0.5 to 5.3 C. During 1977 highest fall catches were observed during December. These data indicated that YOY tolerate a wide range of water temperatures.

Smelt YOY reached a modal length of 50 mm in October and 60 mm in December. Since modal length of YOY was estimated at 40 mm during August, growth rate of YOY was approximately 5 mm per month (0.16 mm/day) from August to December.

Yearlings--

<u>Seasonal distribution</u>--

April--Yearling smelt live in deep water during winter and migrate inshore during spring. During April yearlings were found at all depths in the study area. Few yearlings occurred in shallow water (beach-3 m). They were most common at 6 and 9 m during April 1978 and were evenly distributed from 6 to 15 m during April 1979 and 1980 (Fig. 38). Catches of yearlings per trawl haul during April ranged from 10 to 64 during 1978-1980. High catches during April 1980 (64/trawl haul) were probably related to relatively warm water (3.8-12.0 C) in the study area. Cold water (1.5-10 C) probably delayed the inshore migration of yearlings during April 1979. Only 10 yearlings were caught per trawl haul during April 1979. During April, yearling smelt ranged from 40 to 100 mm. Modal length of yearlings in April (60 mm) was the same as the modal length of YOY observed during December.

May--Catches of yearlings increased dramatically during May. More yearlings were found in shallow water (beach-3 m) during May than during April. During May 1979 higher catches of yearlings were found from the beach zone to 3 m than at 6 and 9 m, or at 12 and 15 m. Most yearlings occurred at 12 and 15 m during May 1978 and 1980 (Fig. 38). Mean catches of yearlings per trawl haul during May were from 112 to 132 individuals during 1978-1980. This large influx of yearlings to the inshore area was caused by increased water temperature in the spring. Mean bottom water temperatures during May ranged from 6.2 to 13.8 C (Fig. 22). Unlike other monthly catches, yearling catch during May varied only slightly over the 3-yr period.

June--Catches of yearlings in the study area generally declined during June due to warming of inshore water (Fig. 38). June catches varied considerably over the 4-yr period. During 1977-1980 catches of yearlings per

trawl haul during June ranged from 7 to 112 individuals. Scarcity of yearlings during June 1979 (7 yearlings/trawl haul) was probably caused by the unusually warm water (7.5-17.0 C) observed during this sampling period. Low catches during June 1977 (36 yearlings/trawl haul) probably resulted from relatively low temperatures which ranged from 5 to 11.7 C from 6 to 15 m. High catches (119 yearlings/trawl haul) were observed during June 1980 in water temperatures ranging from 7.3 to 13.2 C at depths of 6 to 15 m. During June 1978 water temperature was relatively higher at the south transect than at the north transect (Fig. 22). Mean catch of yearlings collected per trawl haul was approximately 87 during June in our study area.

Yearlings were scarce in shallow water (beach-3 m) during June and the remainder of the year indicating that smelt in this size group remain in the shallow area only briefly during May. During June 1977 and 1978 highest catches of yearlings were found at 6 and 9 m, while during 1979 and 1980 yearlings were most common at 12 and 15 m.

July-December--Most yearlings probably live in deep water during the summer. In July large numbers of yearlings sometimes followed upwellings to the inshore area. High catches of yearlings observed during July 1978 and July 1979 (Fig. 38) occurred in relatively cold water. Mean water temperatures from 6 to 15 m ranged from 9.4 to 11.3 C in 1978 and from 5.3 to 9.3 C in 1979 (Fig. 22). During July 1980 yearlings were scarce because of excessively high water temperature (mean temperatures were 18 to 21 C from 6 to 15 m). During July 1977 however, despite a cold-water upwelling (Fig. 22), catches of yearlings were relatively low (Fig. 38).

Yearling catches in the study area continued to decline during August and September. Catches of yearlings per trawl haul ranged from 7 to 36 individuals during these 2 mo. High catches were generally found in cool water (Figs. 22,38). Unlike June and July results, however, few yearlings followed cold-water upwellings to the inshore area. Low temperatures were observed during August 1980 and during September 1977 and 1979 (Fig. 22), but only relatively low catches of yearlings were obtained during these sampling periods (Fig. 38). As has been indicated, yearlings were scarce in the shallow area. Most were caught from 6 to 15 m during July, August and September. Yearlings were scarce during fall. Small numbers of yearlings were found during October, November and December 1980. During fall 1977-1979 yearlings were almost absent from the study area.

Adults--

<u>Seasonal distribution</u>--

April--Adult smelt migrate inshore to spawn during spring. In Lake Michigan spawning takes place mostly during April and May (Daly and Wiegert 1958; Van Oosten 1940). In the study area the spawning run probably started around mid-April during 1978-1980. No adults with spent gonads were caught during 15-17 April 1979 and only a few adults with spent gonads were collected during 23-27 April 1978 and 21-29 April 1980 (Fig. 39). Daly and Wiegert (1958) reported smelt spawning starts only when water temperature increases to

above 4.5 C during spring. Spawning reached a peak at a water temperature of 10 C (Euers 1960; Jude et al. 1975). Near Ludington, Michigan, smelt spawning takes place at water temperatures of 5-7 C (Liston et al. 1980). In the study area ripe-running and spent adults were observed in water temperatures of 4 to 7.8 C during April 1978 and 1980 suggesting that spawning occurred at this temperature range. High catches of adults with ripe-running and spent gonads during late April 1978 and 1979 (Fig. 39) suggested peak spawning of smelt in the study area takes place around the end of April.

Rainbow smelt generally spawn in shallow water (Jude et al. 1979b; Rupp 1959; Van Oosten 1940). Adults with well developed, ripe-running and spent gonads were abundant from the beach zone to 3 m during April suggesting spawning took place at these depths. Largest catches during April, however, were observed at 6 and 9 m. A few adults in spawning condition also occurred at 12 and 15 m. Although rainbow smelt also migrate upstream to spawn, no spawning run was observed in Pigeon Lake or Pigeon River during 1978-1980. No spawning was found in Little Pigeon Creek, a small tributary to Lake Michigan approximately 6 km north of the Campbell Plant. These data indicated that in the vicinity of the Campbell Plant smelt spawning takes place mostly in Lake Michigan.

May--Adult smelt move offshore soon after spawning. Wells (1968) found most adult smelt at 27 m by 5 May and at 36 m by the end of May in eastern Lake Michigan off Saugatuck, Michigan. In Lake Erie, Ferguson (1965) recorded increasing catches of adult smelt in deep water during May. In our study area catches of adult smelt were lower during May than during April 1978 and 1980 (Fig. 38). In 1979, however, adult catches were higher during May than during April because April sampling was conducted before the major spawning run of smelt.

Spawning was still in progress during May during 1978-1980 as some smelt with ripe-running and well developed gonads were found in May catches. Most adult smelt collected during May, however, showed spent gonads (Fig. 39), suggesting that the spawning peak was over before mid-May.

As was observed during April, in May adults were caught from the beach zone to 15 m. During 1978, approximately the same number of adults were collected in shallow water (beach and 3 m) and at 6 and 9 m. A few adults were found at 12 and 15 m. Adults were most common at 6 and 9 m during May 1979 and at 12 and 15 m during May 1980. Occurrence of large numbers of adults with ripe-running and spent gonads from 6 to 15 m, also observed during April, suggested that some spawning takes place at these depths. Smelt spawning was reported to occur in water 9 to 12 m in Lake Heney, Gatineau County, Quebec (Legault and Delisle 1968) and in water 9 to 22 m in Lake Erie (MacCallum and Regier 1970). Because water temperature was generally lower in deep water (Fig. 22), incubation of eggs deposited in deep water was slower than eggs spawned in shallow water. Capture of newly hatched larvae during late June and early July (see RESULTS AND DISCUSSION, Rainbow Smelt, Larvae) substantiated spawning in deep water.

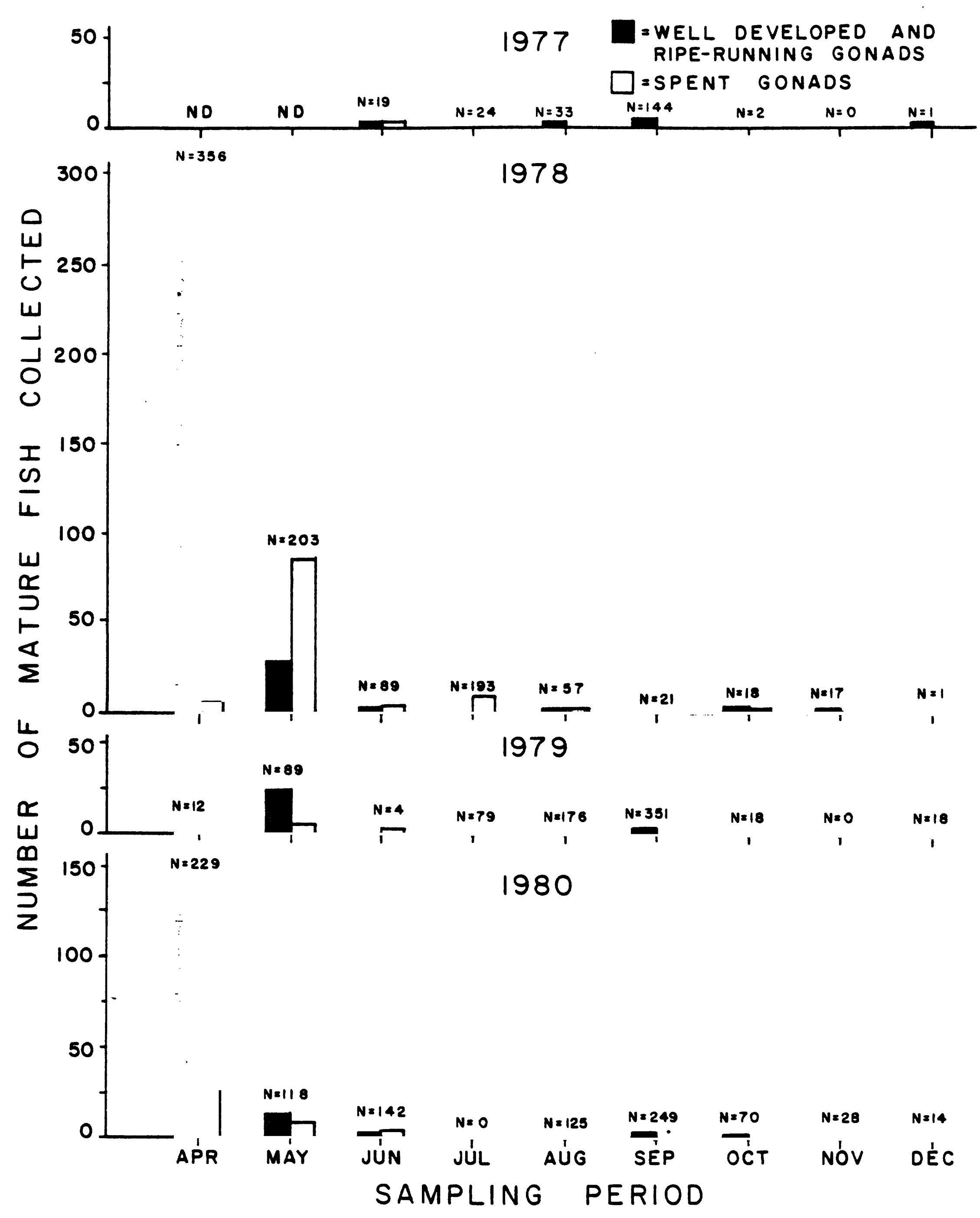


Fig. 39. Number of mature rainbow smelt with well developed, ripe-running and spent gonads collected monthly during June-December 1977 and April-December 1978-1980 near the J. H. Campbell Plant, eastern Lake Michigan. N = total number of mature rainbow smelt caught per month.

June-December--Most adults probably live in deep water during June. Adult smelt were scarce and were found only from 6 to 15 m during this month. No adults with ripe-running or well developed gonads were collected. A few adults collected in June showed spent gonads. Adults moved offshore probably because of the warming of inshore water. They were never observed in the study area in large numbers during June even during cold-water upwellings which occurred during June 1977 and 1980 (Fig. 22).

Catches of adults varied considerably during July, August and September (Fig. 37). Unlike June findings, adults often followed the upwelling of cold water to the inshore area during these 3 mo. Relatively high catches of adults were observed during upwellings of cold water as was found during July 1978, August and September 1979 and 1980, and September 1977 (Figs. 38,22). During 1978 substantial catches of adults were observed during July when mean bottom temperature ranged from 7.6 to 12.2 C (Fig. 22). During 1979 high catches of adults occurred during August and September. Mean bottom temperatures from 6 to 15 m were 14 to 14.9 C during August and from 10.5 to 13.0 C during September. In 1977 adults were common during September when mean bottom temperatures were 6.5 to 10.0 C from the beach zone to 15 m. Although water temperature was relatively high (Fig. 22), adults were also caught in substantial numbers during August and September 1980 (Fig. 38). Adults were scarce in the study area during fall. No adults were caught during October, November or December 1977. A few adults were collected during fall 1978-1980.

Smelt populations in the study area appeared to increase during the period 1977-1980 (Table 28). During 1977 yearling and adult catches were substantially lower than in other years due to the lack of sampling during April and May, times when two size groups were most abundant. Adult catches were relatively low and did not vary greatly during 1978-1980. Low catches of adults during 1979 were due to a poor spawning run during the April and May sampling periods. Yearling catches fluctuated widely during 1977-1980 (Table 28). High catches of yearlings observed during 1978 may have resulted from a strong year class and from favorable temperatures in inshore water. The increasing abundance of YOY during 1977-1980 made up the major portion of the increase in total catches of rainbow smelt.

Plant Effects--

During May and June 1978 mean densities of smelt larvae were slightly higher at the south reference than the north transect. During early July and early August 1978, however, smelt larvae appeared to be more common on the north than the south transect (Table 27). The Wilcoxon signed ranks test ($\alpha = 0.05$) showed no significant difference in larval smelt densities between the north and south transects during 1978.

During 1979 smelt larvae were more abundant at the north than the south reference transect during all sampling periods (Table 27, Wilcoxon signed ranks test, $\alpha = 0.05$). This difference resulted mainly from the high catches of larvae at the north transect during May and late June (Table 27). As was found during 1979, larval densities were significantly higher at the north

Table 28. Number of rainbow smelt caught by all gear types during June-December 1977 and April-December 1978-1980.

Life stages	Year 1977	1978	1979	1980
Adults	320	1155	987	1369
Yearlings	1452	14368	6271	4285
YOY	11131	9838	22770	26043
Total	12903	25351	29028	36697

than the south transect during 1980 ($\alpha = 0.05$, Wilcoxon signed ranks test). Smelt larvae were more abundant at the north transect during all sampling periods in 1980. Largest difference in mean densities between the two transects, however, was observed during May.

Higher catches of smelt larvae at the north transect than at the south reference transect during 1979 and 1980 may be related to the construction of offshore intake and discharge structures for Unit 3. During 1979 and 1980 rock riprap made of 10- to 20-cm diameter rubble was laid on the bottom from shore to 11 m to cover the underground pipelines. More adult rainbow smelt may spawn on this rubble than on the sandy bottom. Smelt eggs laid on rocky substrate have a survival rate 10 times greater than those laid on sand because sand has a grinding effect on eggs under the influence of the surf (Rupp 1965). Higher larval density at the north transect may in part be due to a higher survival rate experienced by smelt eggs laid on rocky substrate. Bottom dredging and the rocky riprap may cause an increased food supply for smelt larvae at the north transect during 1979-1980.

Catches of smelt in trawls at the reference station (6 m, south) and the plant transect station (6 m north) were not significantly different during 1977 (Jude et al. 1978). The ANOVA results for trawl data for 1977-1980 showed that the STATION and AREA effects were highly significant (Tables 29 and 30). Geometric mean abundances of smelt at 6 and 9 m were significantly higher at the plant transect than at the reference transect. While during 1978 geometric mean catches were only slightly higher at the plant transect than at the reference transect, substantially higher catches were observed at the plant transect than at the reference transect during 1979 and 1980 (Fig. 40). Trawl catches included mostly YOY and yearlings. Adult smelt were generally caught in low numbers in trawls. Higher catches of rainbow smelt at the north transect during 1979 and 1980 resulted mainly from greater abundance

of YOY and yearlings in this part of the study area. Preparation of the bottom for construction of the intake and discharge structures may have caused an increased food supply which attracted yearlings and YOY to the north transect. During spring more yearlings were caught at the reference transect.

Table 29. Analysis of variance summary for rainbow smelt caught in trawls at stations C (6 m, south) and L (6 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1977 through 1980. Data for June through December were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	3	0.1351	1.0336	0.3806
Month	6	6.2848	48.0957	<0.0001**
Station	1	1.5421	11.8014	0.0008**
Time	1	7.0490	53.9445	<0.0001**
Y x M	18	2.7432	20.9928	<0.0001**
Y x S	3	0.1183	0.9055	0.4409
M x S	6	0.1655	1.2668	0.2784
Y x T	3	0.3292	2.5194	0.0616
M x T	6	0.7237	5.5379	<0.0001**
S x T	1	0.1700	1.3007	0.2565
Y x M x S	18	0.2116	1.6190	0.0669
Y x M x T	18	0.4774	3.6532	<0.0001**
Y x S x T	3	0.3999	3.0607	0.0312
M x S x T	6	0.1572	1.2028	0.3101
Y x M x S x T	18	0.2181	1.6693	0.0554
Within cell error	112	0.1307		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

Spottail Shiner

Introduction--

Spottail shiners are benthic minnows of shallow areas of large lakes and rivers. They are found in all the Great Lakes and are abundant in Green Bay and the southeastern region of Lake Michigan (Wells and House 1974). This study found them to be very abundant in the vicinity of the J. H. Campbell Plant during preoperational study years. Numerically they were the third-most abundant fish in 1977-1980 comprising 10, 14, 12 and 18% of the total catch in 1977, 1978, 1979 and 1980 respectively (Table 10).

Spottail shiners were collected in all months that sampling was performed. Typically spottails began a shoreward migration in April and May, which was complete by June. Spawning occurred in June and July and was usually completed by early August. During spawning fish were concentrated in the beach zone; when water temperatures were warm enough ($\geq$ 15.0 C) they were

Table 30. Analysis of variance summary for rainbow smelt caught in trawls at stations C (6 m, south), D (9 m, south), L (6 m, north) and N (9 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1978 through 1980. Data for May through December were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	2	2.2289	16.6865	<0.0001**
Month	7	7.5611	56.6052	<0.0001**
Area	1	2.3919	17.9065	<0.0001**
Depth	1	3.1837	23.8346	<0.0001**
Time	1	3.2010	23.9639	<0.0001**
Y x M	14	4.6116	34.5246	<0.0001**
Y x A	2	0.2093	1.5668	0.2114
M x A	7	0.4339	3.2481	0.0028*
Y x D	2	0.9564	7.1598	0.0010*
M x D	7	0.4726	3.5377	0.0013*
A x D	1	0.4170	3.1217	0.0788
Y x T	2	0.5750	4.3050	0.0148
M x T	7	1.4513	10.8649	<0.0001**
A x T	1	0.0067	0.0503	0.8228
D x T	1	3.4875	26.1089	<0.0001**
Y x M x A	14	0.7281	5.4506	<0.0001**
Y x M x D	14	0.5299	3.9671	<0.0001**
Y x A x D	2	0.3804	2.8476	0.0604
M x A x D	7	0.2327	1.7417	0.1014
Y x M x T	14	1.0962	8.2068	<0.0001**
Y x A x T	2	0.4926	3.6879	0.0268
M x A x T	7	0.2601	1.9474	0.0643
Y x D x T	2	0.7006	5.2450	0.0061*
M x D x T	7	0.3210	2.4033	0.0222
A x D x T	1	0.1684	1.2609	0.2629
Y x M x A x D	14	0.1406	1.0527	0.4033
Y x M x A x T	14	0.3623	2.7126	0.0012*
Y x M x D x T	14	0.1647	1.2331	0.2540
Y x A x D x T	2	0.2216	1.6589	0.1931
M x A x D x T	7	0.0850	0.6363	0.7255
Y x M x A x D x T	14	0.0885	0.6624	0.8089
Within cell error	192	0.1336		

** Highly significant ($P < 0.001$).
* Significant ($P < 0.01$).

found out to 6 m. Peak numbers of adult spottails were found in the study area from late June through August. By August adults vacated the beach zone and migrated to deeper water with concentrations at 6 and 9 m. Spottail larvae were concentrated between the beach and 3 m during June through August. Upwellings have a profound effect upon spottail spawning and hatching success. Highest larval densities occurred when spawning was not interrupted by upwellings (e.g., 1980). Spottail larvae were rarely caught at depths exceeding 3 m. Larval spottails in our samples seldom exceeded 15 mm TL. The

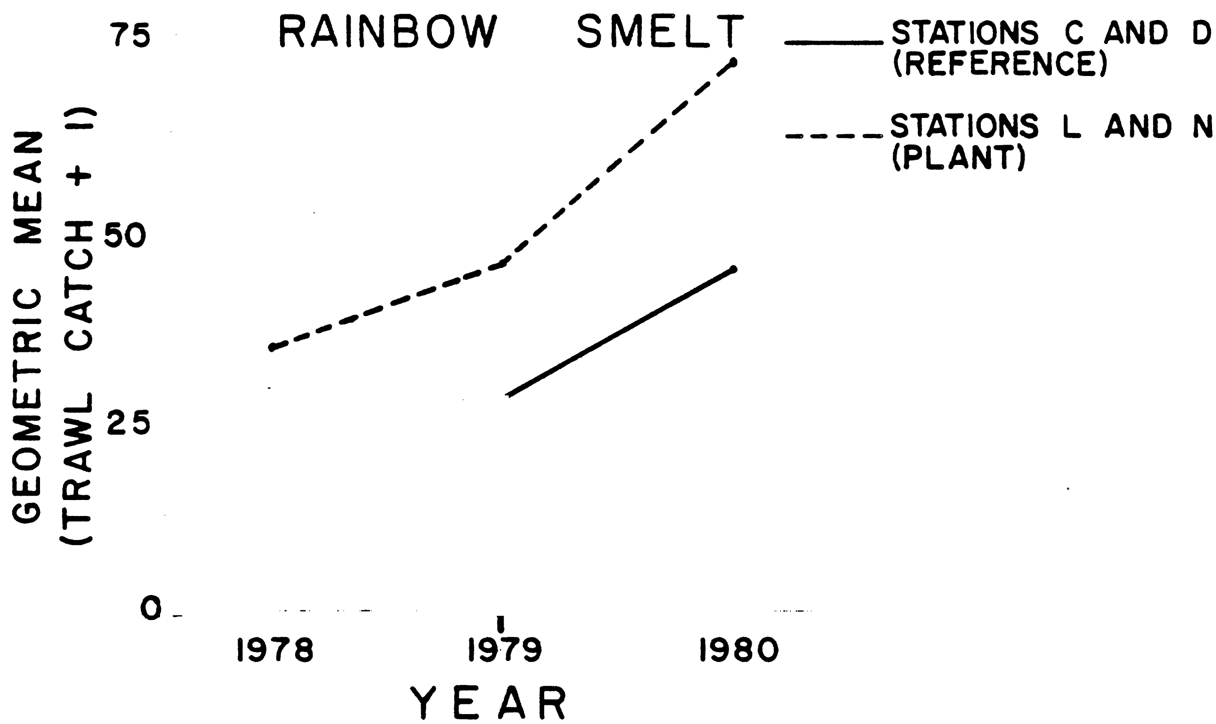


Fig. 40. Geometric mean number plus one of rainbow smelt caught in trawls at stations C (6 m, south), D (9 m, south), L (6 m, north) and N (9 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1978 through 1980. Graph illustrates the YEAR x AREA interaction.

beach zone is a very important spawning and nursery area for spottails as evidenced by the high larval and YOY densities found there. YOY spottails remained in the beach zone through September and began a migration to deeper water by October, following the outward migration of adults. By November and December adults were beyond 15 m; YOY fish were at 12 m or deeper.

Larvae--

Introduction--Cyprinids were the most difficult fish larvae to identify and most were classified as unidentified minnows in 1977 and 1978. Increased expertise in larval fish identification eliminated most unidentified minnows from 1979 and 1980 samples. Since we felt from 1979 and 1980 data that most unidentified minnows in 1977-1978 were spottails, we designated all unidentified minnows collected in 1977-1978 as spottails.

Seasonal distribution--

April and May--During 1980, no spottail larvae were collected during April and May and only a few were caught at the north transect during this period in 1979. Early spring water temperatures were usually too cold for

spottail spawning and hatching, which occur at water temperatures of approximately 15-20 C for this species (Heufelder and Fuiman in press). No spottail larvae were collected during April-May, 1978.

June--The first major occurrence of spottail shiner larvae in the vicinity of the Campbell Plant during the preoperational period was always noted in June (Figs. 41-53). During June of preoperational years spottail larvae were primarily distributed at depths of 3 m or less and were 5 mm or less in length, indicating that they were newly hatched. During early June 1977, 1979 and 1980, spottail larvae were collected at the north transect, but not at the south, while in early June 1978 mean densities at north and south transects were comparable. Mean densities in early June over the 4 yr study were less than 1000 larvae/1000 m^3 and larvae were caught primarily in 3 m of water or less. Larval densities in late June were generally less than 1000 larvae/1000 m^3 (except at the north transect in late June 1979), suggesting some spawning occurred during late May and early June of these years. No spottail larvae were caught in June 1978. In June of all years, maximum densities of spottail larvae were collected when water temperatures were warmest.

July--Mortimer (1975) gave a detailed description of upwellings which we have found can have a pronounced effect upon the distribution of larval spottail shiners as well as other species in Lake Michigan through the mechanism of depressing spawning activity. The contrast in larval spottail shiner densities during early July 1979 and 1980 clearly demonstrates the effect of this phenomenon. A cold-water upwelling in early July 1979 caused an interruption in spottail spawning and substantially reduced densities of spottail larvae. In late June 1979, when mean water temperature was about 14.5 C at north and south transect beach to 3-m stations, mean densities of 1400 and 300 larvae/1000 m^3 respectively were recorded. During early July, mean water temperature was about 10.0 C and mean densities were only 100 larvae/1000 m^3 or less at beach to 3-m stations. During early July 1980 when no upwelling occurred, mean density of spottail larvae was 7000/1000 m^3 at the south transect beach to 3-m stations when the mean temperature was 16.9 C. During periods of upwellings, densities of spottail larvae were higher at the north transect beach to 3-m stations than at the south transect. For example, mean densities of 20 larvae/1000 m^3 were observed at the south beach to 3-m stations vs. mean densities of 100 larvae/1000 m^3 at north beach to 3-m stations in early July 1979. Although Lake Michigan waters were too cool for spottail spawning and hatching, spottail spawning may have continued in the discharge channel and larvae washed into Lake Michigan at the north transect.

During early July 1977 and 1980, when no upwellings occurred, high mean densities of spottail larvae were observed at both north and south transect beach to 3-m stations. During early July 1977 mean densities ranged from 1400 larvae/1000 m^3 to 3500 larvae/1000 m^3 at beach to 3-m stations. In early July 1980 mean densities at beach to 3-m stations ranged from 3000 larvae/1000 m^3 at the north transect to 8000 larvae/1000 m^3 at the south transect. Water temperatures were approximately 17.0 C at both north and south transect beach

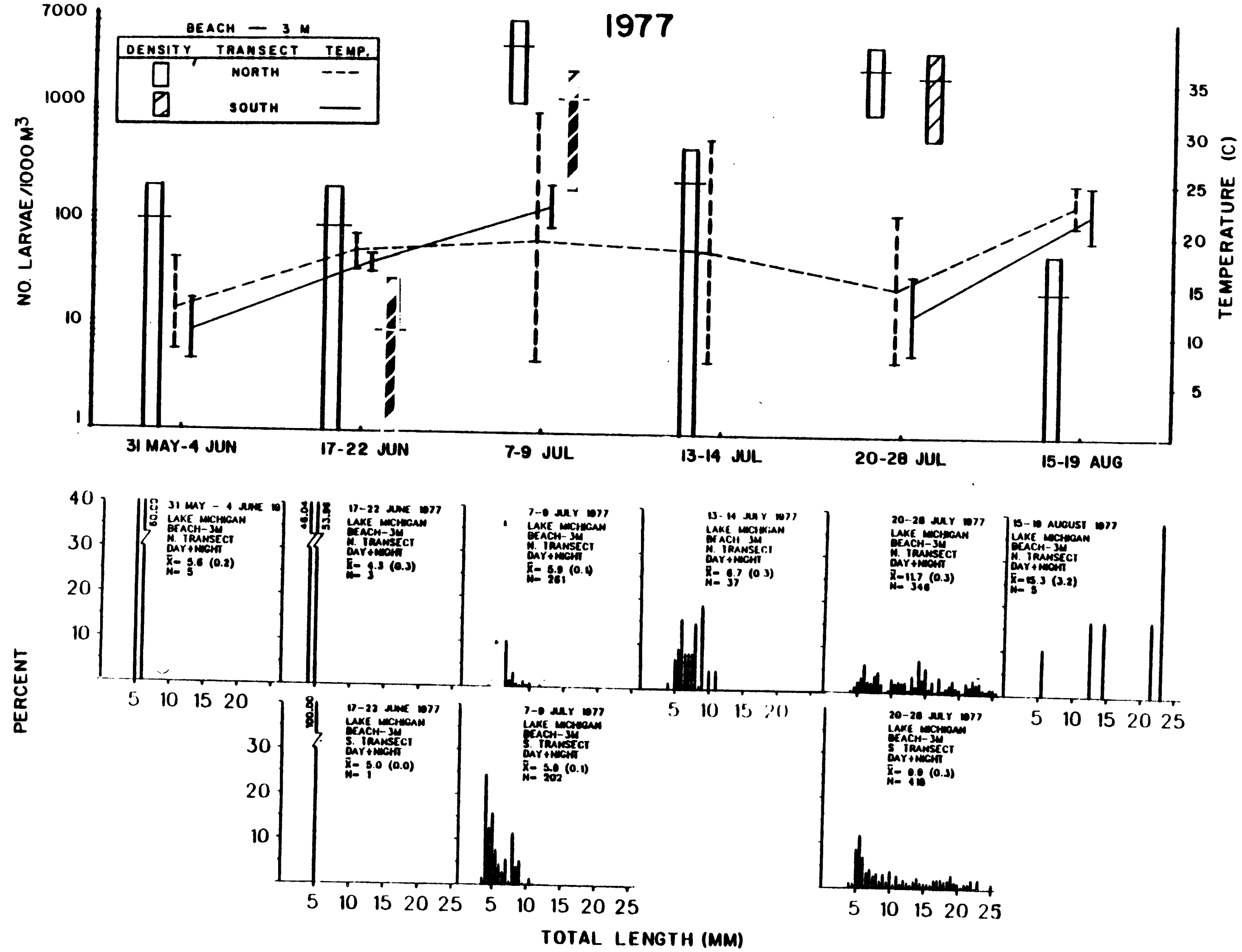


Fig. 41. Density (no./1000 M^3 plotted on log scale) of larval spottail shiners collected during June to September 1977 at beach - 3 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

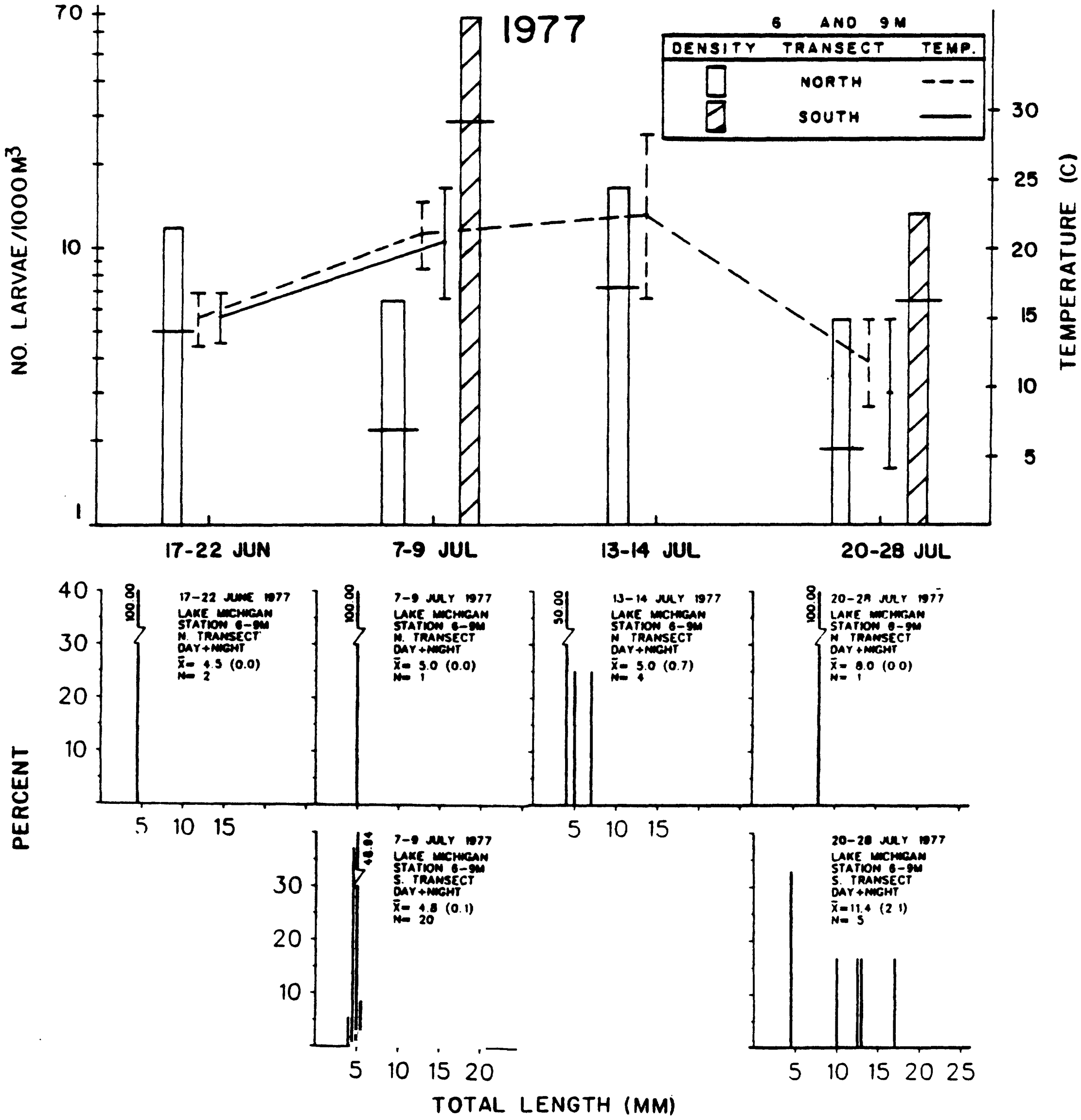


Fig. 42. Density (no./1000 M^3 plotted on log scale) of larval spottail shiners collected during April to September 1977 at 6 and 9 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

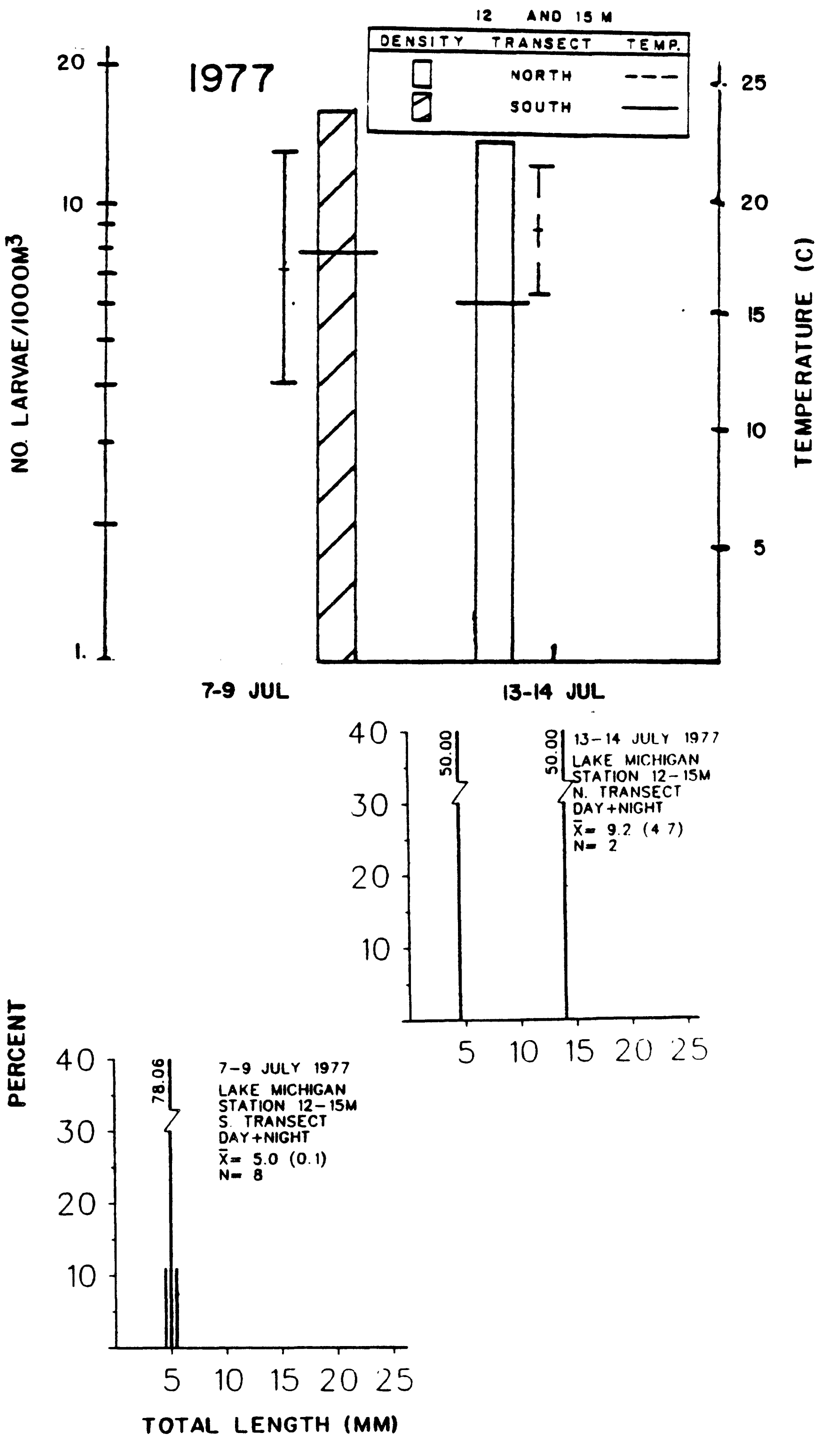


Fig. 43. Density (no./1000 M^3 plotted on log scale) of larval spottail shiners collected during June to September 1977 at 12 and 15 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

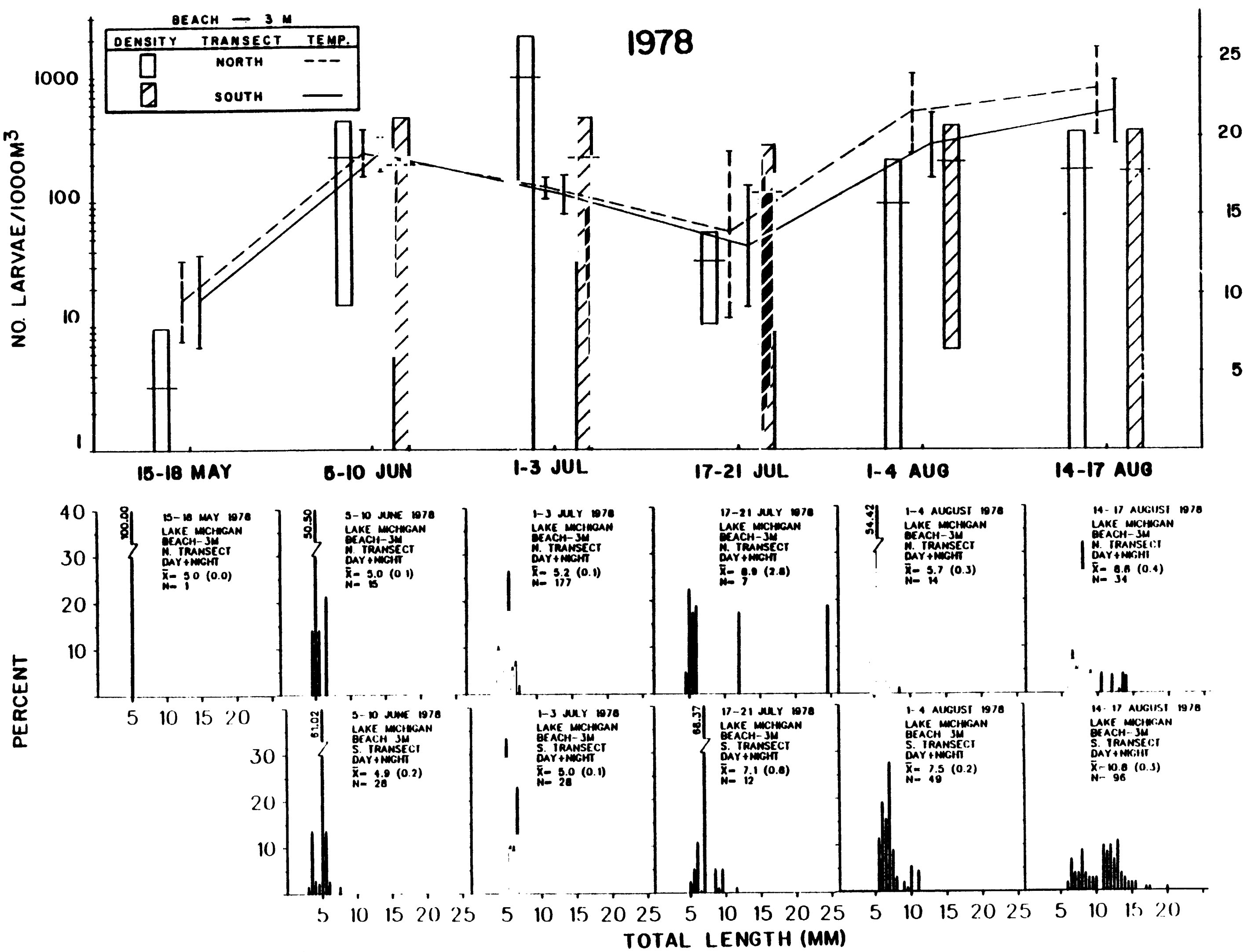


Fig. 44. Density (no./1000 M^3 plotted on log scale) of larval spottail shiners collected during April to September 1978 at beach - 3 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

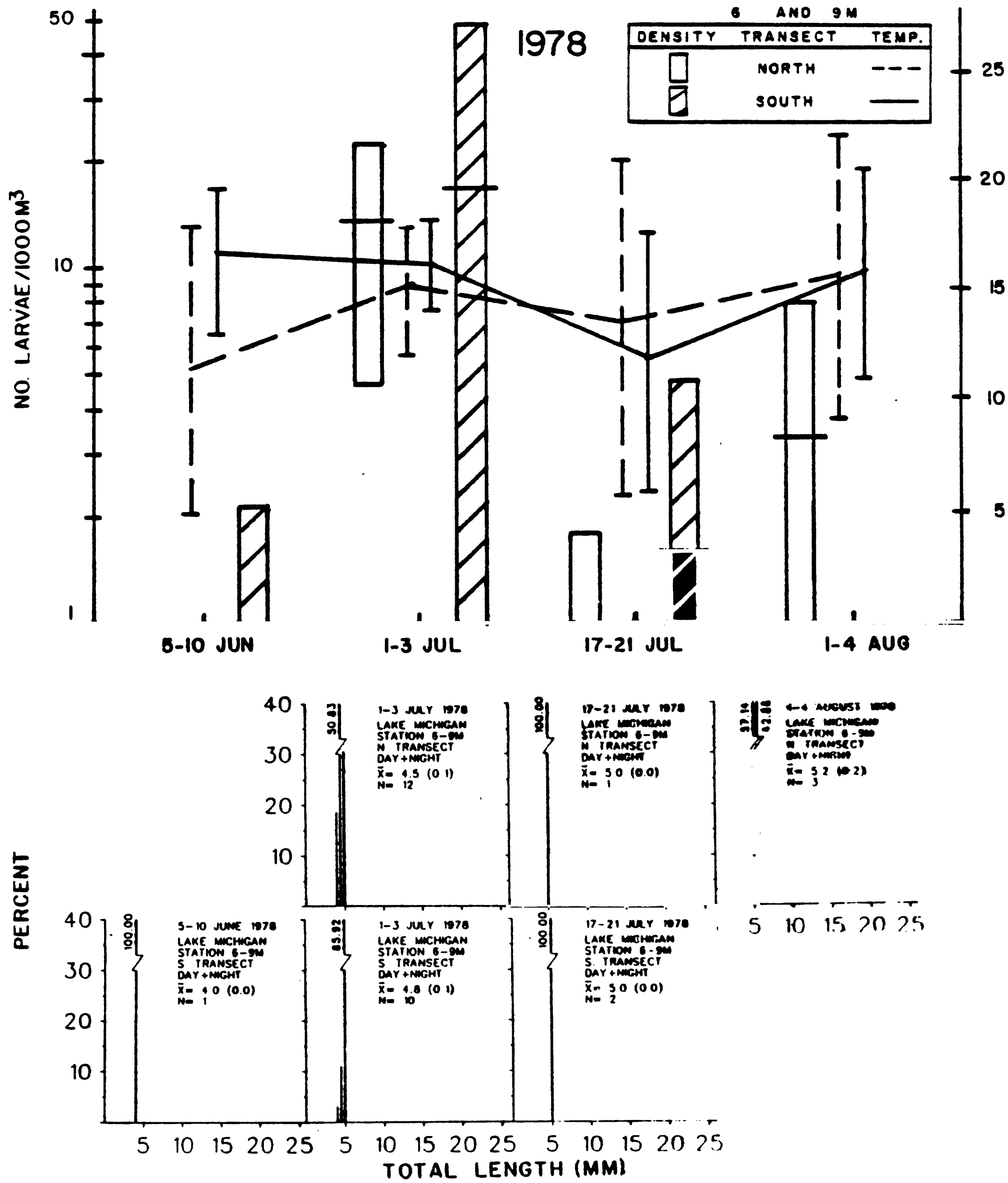


Fig. 45. Density (no./1000 M^3 plotted on log scale) of larval spottail shiners collected during April to September 1978 at 6 and 9 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

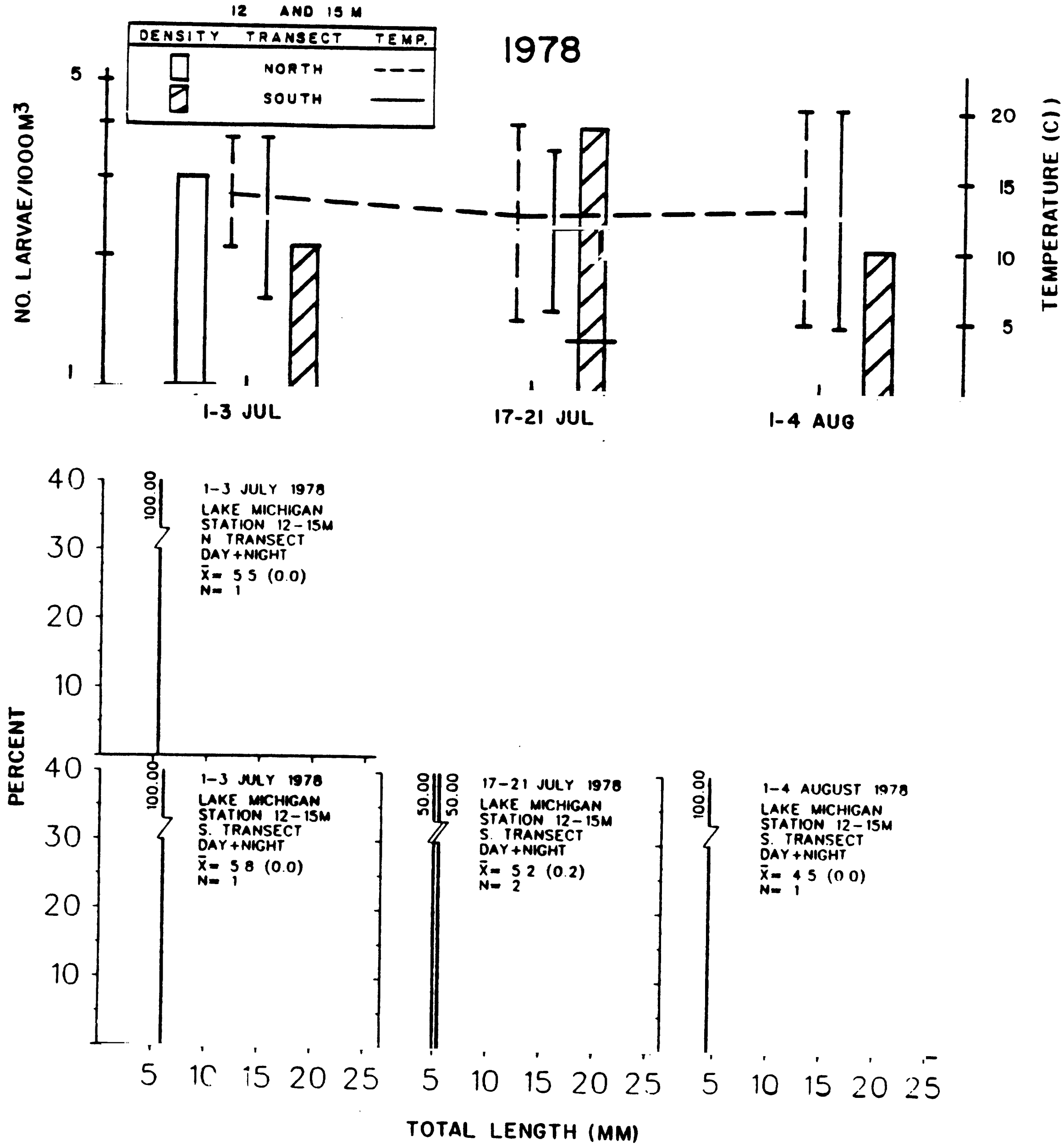


Fig. 46. Density (no./1000 M^3 plotted on log scale) of larval spottail shiners collected during April to September 1978 at 12 and 15 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

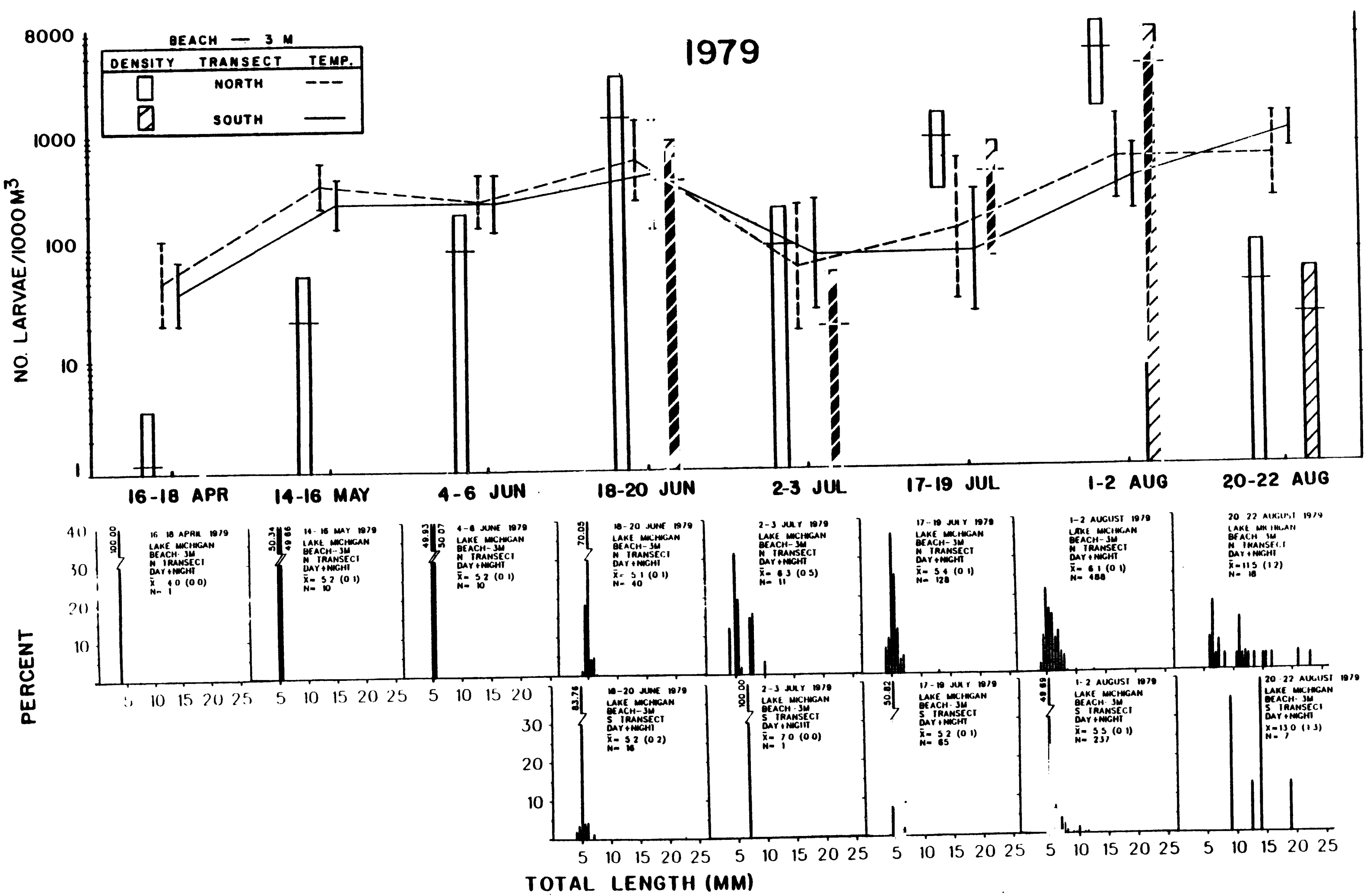


Fig. 47. Density (no./1000 M^3 plotted on log scale) of larval spottail shiners collected during April to September 1979 at beach - 3 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

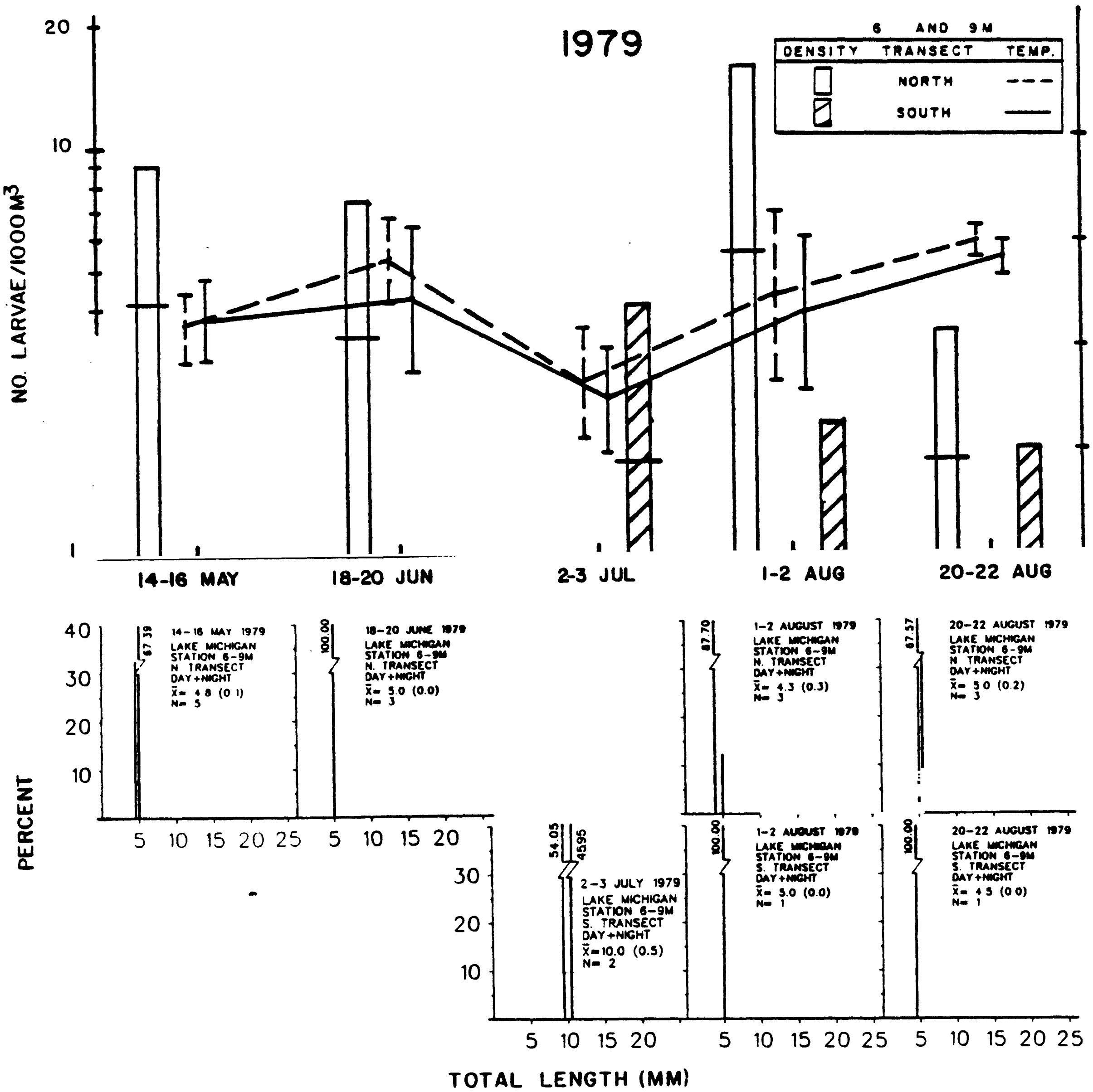


Fig. 48. Density (no./1000 M^3 plotted on log scale) of larval spottail shiners collected during April to September 1979 at 6 and 9 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

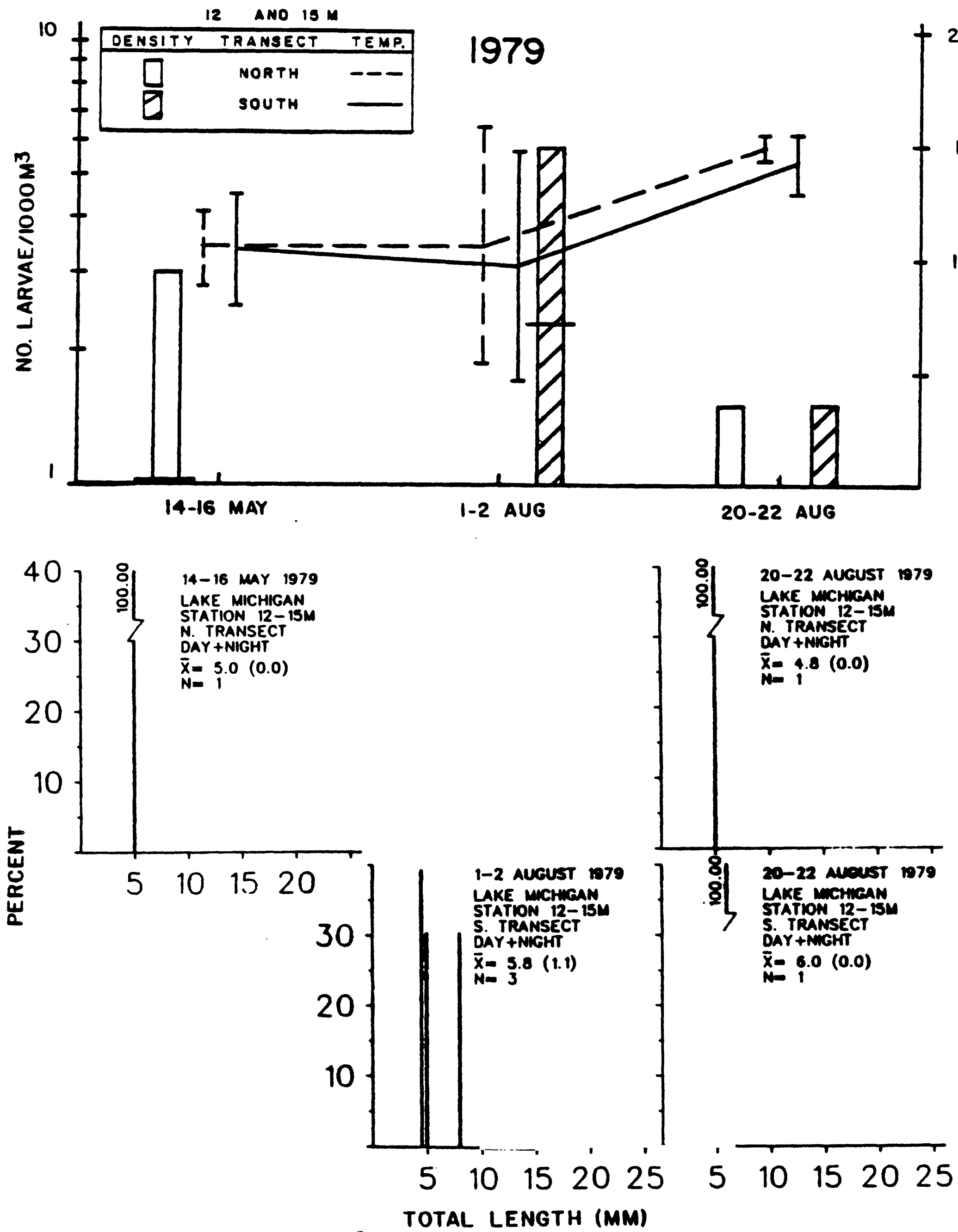


Fig. 49. Density (no./1000 M^3 plotted on log scale) of larval spottail shiners collected during April to September 1979 at 12 and 15 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

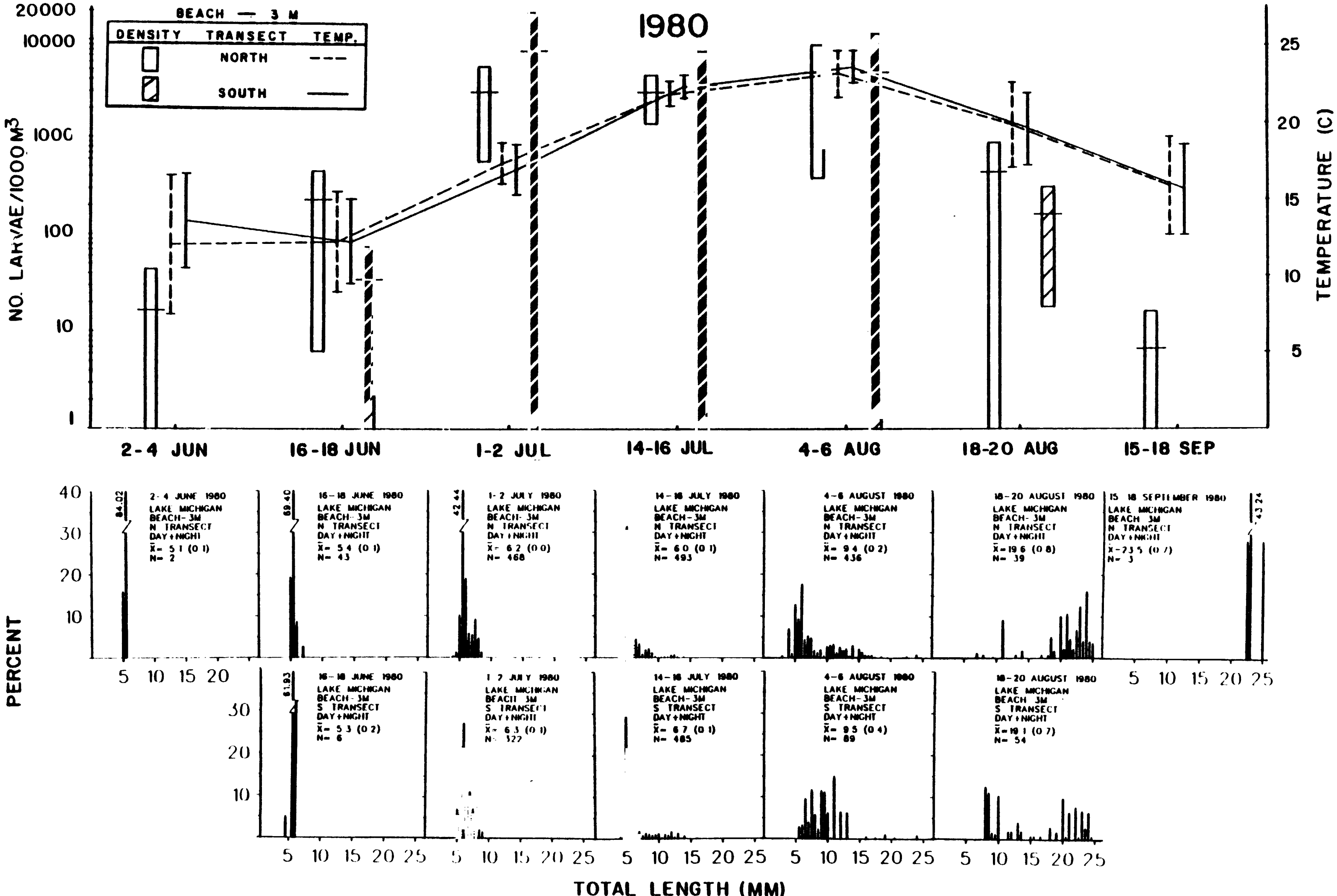


Fig. 50. Density (no./1000 M^3 plotted on log scale) of larval spottail shiners collected during April to September 1980 at beach - 3 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

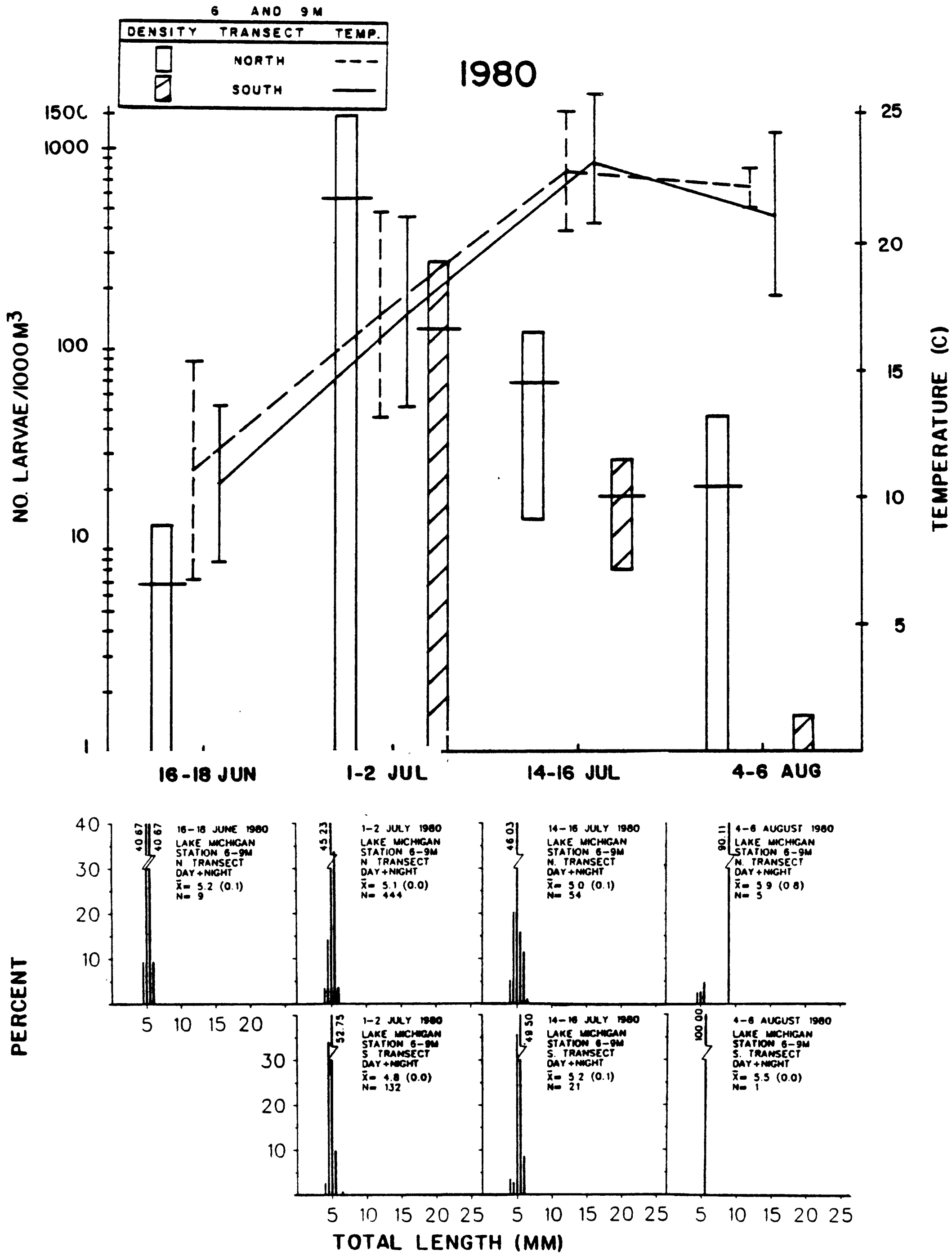


Fig. 51. Density (no./1000 M^3 plotted on log scale) of larval spottail shiners collected during April to September 1980 at 6 and 9 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

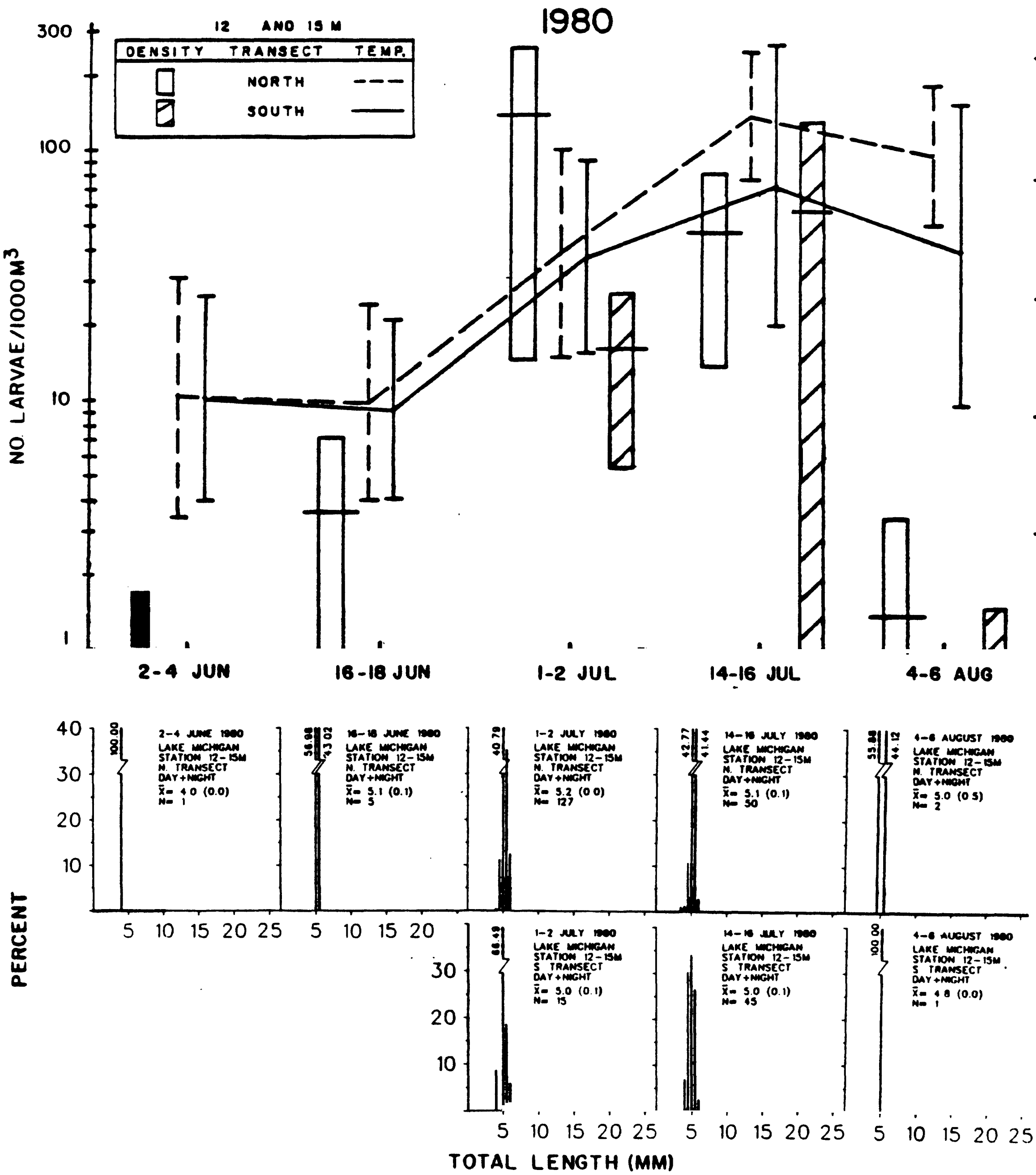
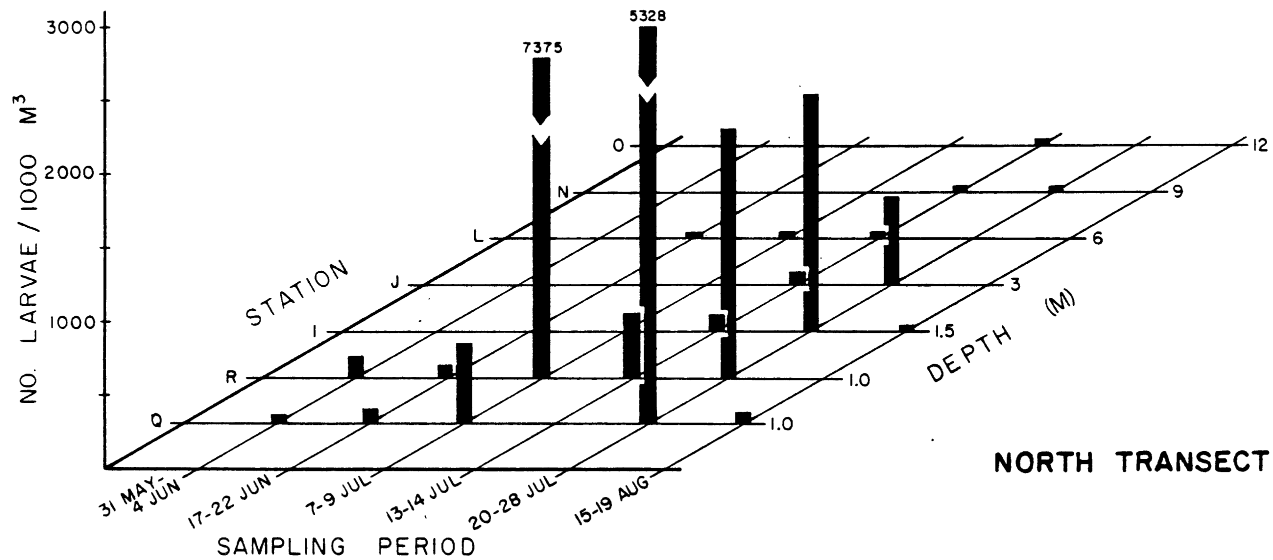


Fig. 52. Density (no./1000 M^3 plotted on log scale) of larval spottail shiners collected during April to September 1980 at 12 and 15 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

1977



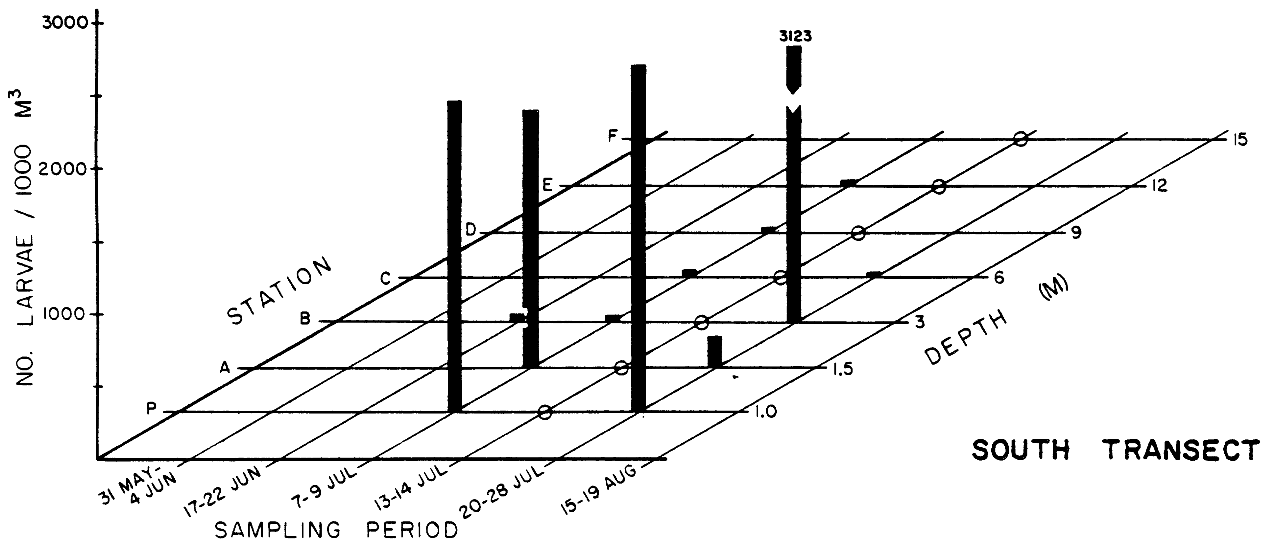
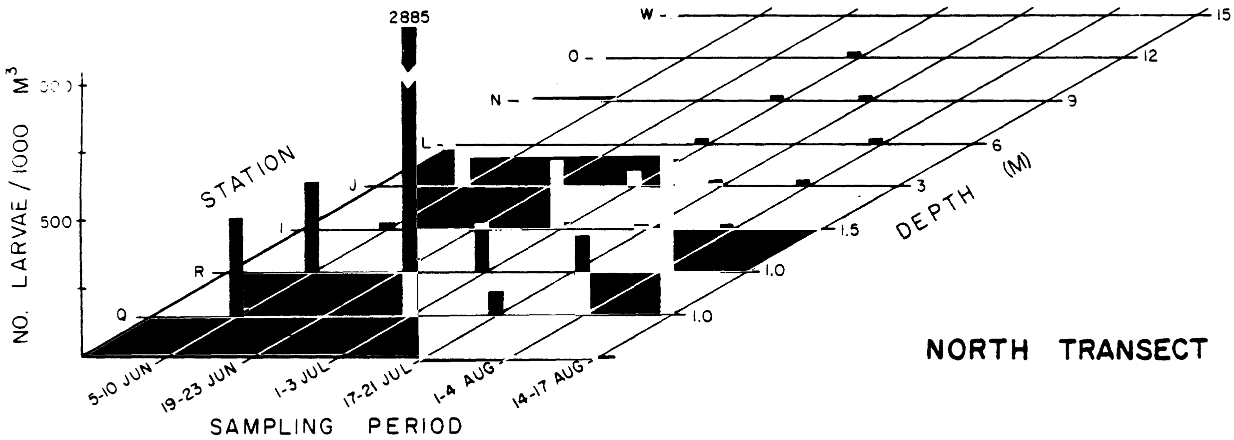


Fig. 53. Mean density (no./1000 m^3) of larval spottail shiners for north and south transect stations in Lake Michigan near the J. H. Campbell Plant, 1977 to 1980. Mean densities were calculated by averaging densities over all gear (plankton nets and sleds), strata and diel periods (day and night) sampled. O = no sampling performed.

1978



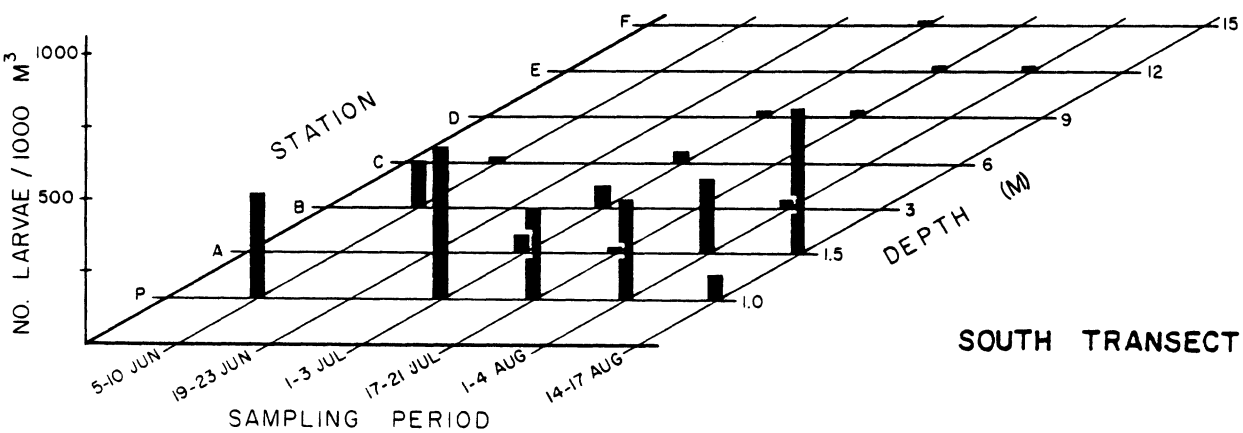
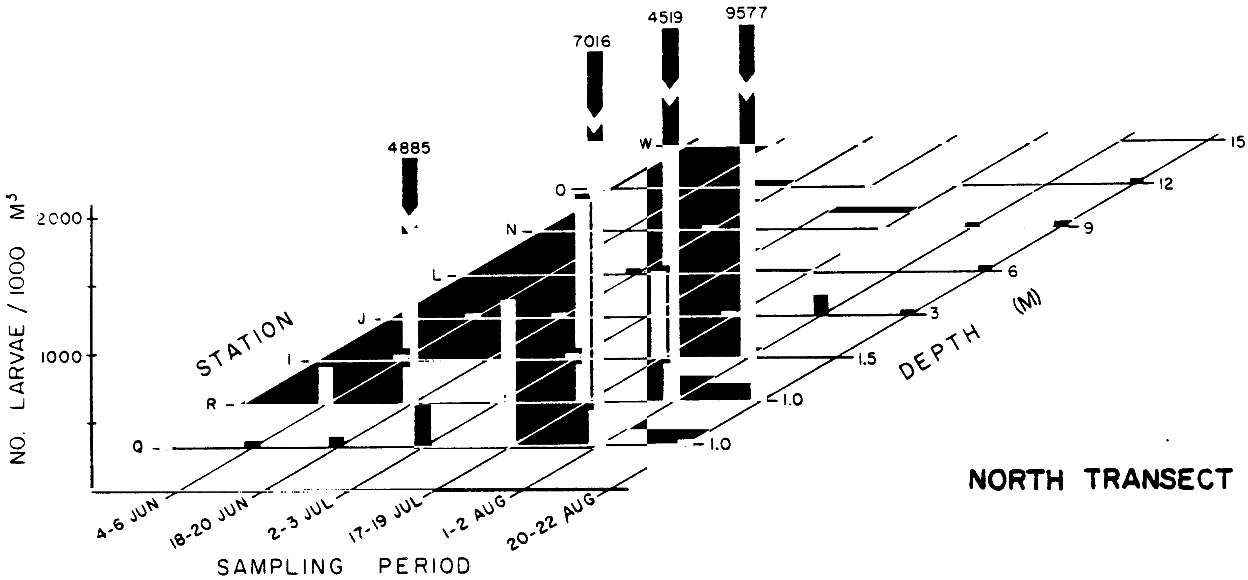
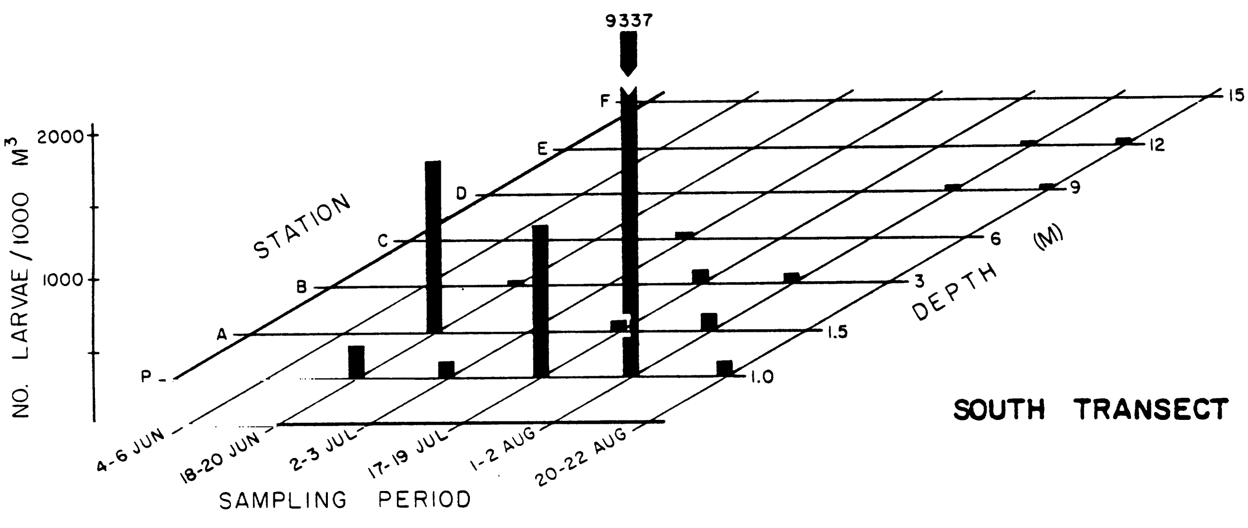


Fig. 53. Continued.

1979





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1980

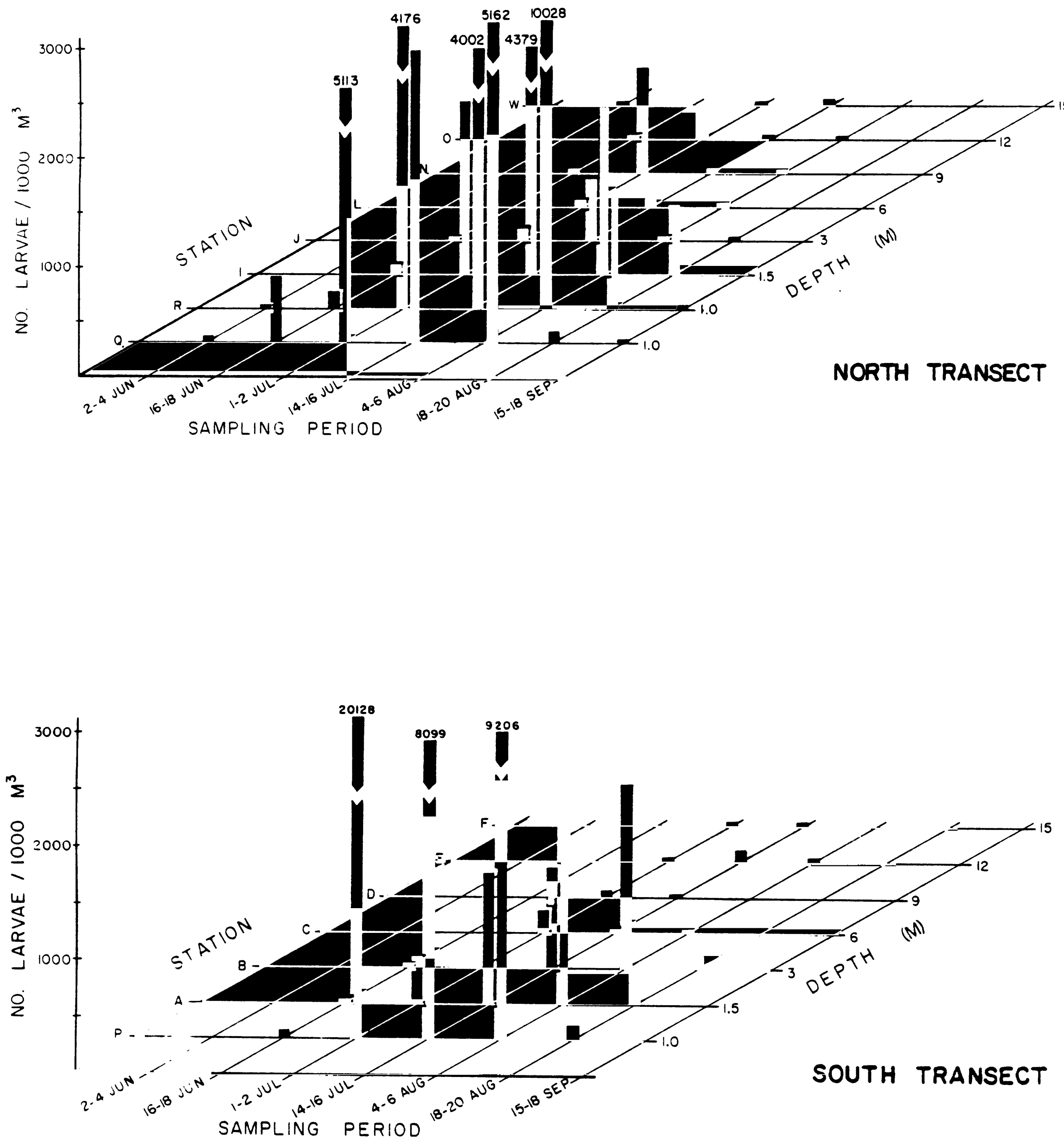


Fig. 53. Continued.

stations. During early July of all 4 yr spottail larvae were most concentrated in 3 m of water or less (Figs. 41-52); nearly all were newly hatched larvae approximating 5 mm in length.

Larval spottail distribution in late July was closely related to water temperature prior to and during sampling. In 1977 densities remained comparable from early July to late July. Water temperatures (Figs. 41-52) were not as high in late July as earlier in the month; consequently, lower densities were found in late July. Mean densities at beach to 3-m stations during late July were from 2500 larvae/1000 m^3 to 3000 larvae/1000 m^3 with little variation between transects. Outside the 3-m depth contour in late July 1977 larval fish densities were low. From 6 to 15 m mean densities were less than 10 larvae/1000 m^3 at both transects. In late July 1978 water temperatures declined from those observed in early July and a concomitant decline in spottail larvae densities was also observed (Figs. 44-46). Spottail larvae were almost exclusively restricted to 3 m of water or less in late July 1978. Modal length of those caught in late July was 8 mm suggesting that spawning and hatching was suppressed during late July 1978 due to depressed water temperatures. As water temperatures warmed during late July 1979 there were increased densities of spottail larvae at all Lake Michigan stations 3 m and less (Fig. 47); mean size of larvae caught at this time was 5.3 mm, suggesting that most were recently hatched. As has been typical in all years sampled, when spottail larvae were present at north and south transects, they were more abundant at north stations near the discharge. Mean spottail larvae densities were very low ($\leq$ 30 larvae/1000 m^3) at depths greater than 3 m of water (Figs. 41-52).

The intensive spawning and hatching activity observed in early July 1980 continued into the latter part of the month due to a lack of interruption of the summer warming trend. Mean densities of larval spottails exceeded 2000 larvae/1000 m^3 at beach to 3-m stations at both transects. During late July mean densities of 20-70 larvae/1000 m^3 were found at 6- to 9-m stations at the north and south transect, but densities declined somewhat at greater depths. Mean length of larvae caught at the beach to 15 m in late July 1980 was 5.4 mm (Fig. 51), suggesting spawning and hatching was ongoing between the beach and 15 m. Data from 1980 suggest that if an upwelling does not occur in July, permitting an uninterrupted warming trend, intensive spawning and hatching activity will occur from the beach to 9 m for the entire month.

August--During 1977, sampling was performed only once during August and a pronounced decline in densities from July levels was noted. Highest mean densities at any station were less than 30 larvae/1000 m^3 with maximum densities found at beach to 3-m stations (Figs. 41-43). No spottail larvae were caught beyond the 3-m depth contour. A mean length of 15.3 mm in August 1977 indicated that spawning and hatching subsided after July.

During early August 1978 the only appreciable densities of spottail shiner larvae were at depths of 3 m or less (Figs. 44-46). Highest mean densities were found at south transect beach stations and length-frequency

data showed a high percentage of recently hatched larvae (mean length = 5.7 mm, SE = 0.3) indicating that spottail spawning had continued until at least late July during 1978.

Highest mean densities of spottail larvae collected during 1979 were noted in early August. Spottail larvae at this time were primarily distributed from the beach to 3 m (Figs. 47-49), although sporadic occurrences of lower mean densities at deeper stations were observed. Length-frequency data indicated that many larvae caught in early August 1979 (over 50%) were 6 mm or less and probably recently hatched, indicating that spottail hatching continued through late July 1979.

During early August 1980 mean densities of spottail shiner larvae remained very high at beach to 3-m stations. Mean densities between 4000 and 5000 larvae/1000 m^3 at both south and north beach to 3-m stations were found. These were the highest densities of spottail larvae noted for early August of any study year. Larvae were concentrated in 1-3 m of water; all station groupings deeper than 3 m had mean densities less than 40 larvae/1000 m^3. Length-frequency data showed that over 50% of the spottail larvae caught in early August were around 6.0 mm indicating that hatching and spawning continued through late July 1980. High densities of larvae noted in early August 1980 were presumably due to the lack of upwellings in 1980 allowing spawning to continue uninterrupted. Late August collections during all years, except 1978 when mean densities from early to late August were comparable, showed a marked decrease from early August densities of spottail shiner larvae. As in previous months densities were greatest at beach to 3-m stations (Figs. 41-52) with sporadic low densities at deeper stations. During all 4 yr few larvae less than 6.5 mm were collected in late August which suggests that spottail spawning and hatching does not occur past early August in Lake Michigan in the vicinity of the Campbell Plant, even when optimal conditions exist for the entire summer, as occurred during 1980.

During September 1977-1979 no spottail larvae were collected in Lake Michigan, probably due to growth of fish and net avoidance. A few spottail larvae were caught at north transect beach stations during 1980, most likely because of optimal conditions which existed during that spawning season.

Young-of-the-Year--

Spottails may become sexually mature when they are 1-yr old (Wells and House 1974). Jude et al. (1979a) reported a size range of 35-74 mm by April for yearlings. Wells and House (1974) found that spottail growth did not begin until June in southeastern Lake Michigan; therefore, yearlings would be the same length range (35-74 mm) from late fall the year before into June. By July few fish under 50 mm were caught, demonstrating that considerable growth occurs in June and July. By August yearlings cannot be distinguished from smaller adults in length-frequency plots.

Seasonal distribution--

August--YOY spottails first appeared in mid-August in the study area. Due to yearly fluctuations in water temperatures during spawning, sizes of YOY spottails varied by month depending upon spawning time. Jude et al. (1979b) found that in 1973 and 1974 YOY spottails had grown to 15-44 mm by August, 25-54 mm by September and 25-64 mm by October in southeast Lake Michigan. Wells and House (1974) found an average length of 79 mm for spottails at the end of their first year of growth in southeastern Lake Michigan. From their data a maximum length range of 65-79 mm would be achieved by November and December. These length ranges will be used to define YOY spottail (by month) in the following discussion of YOY spottail distribution in our study area.

In 1977 YOY spottails first appeared in August beach seine hauls (Fig. 54) and were caught mostly during the day. Although little water temperature variation existed among beach stations, most were caught at the north transect beach stations in August 1977. August 1978 distribution of YOY spottails was quite similar to that observed during the same period in 1977. Nearly all were caught during the day, with equal distribution between north and south transects. Water temperatures ranged from 23.0 to 25.7 C at beach stations. No YOY spottails were caught in trawls during August 1978 indicating that YOY spottails were concentrated in 1.5 m of water or less.

YOY spottails were nearly absent from our catches in August 1979; less than 10 were collected. Upwellings, which interrupted spawning during 1979, apparently precluded the development of spottail larvae to the YOY stage by August in 1979.

Because there was no interruption in spottail spawning and hatching in 1980 (due to lack of upwellings), YOY spottail shiners had grown to 45 mm by mid-August. In stark contrast to their near absence during August 1979, nearly 250 YOY spottails were seined in August 1980. Most were seined during the day at the north transect where the water temperature was slightly warmer (22.6 C) than at the south transect (20.2 C). During August of all years, YOY spottail shiners were caught during the day in 1.5 m of water or less. The diel catch difference observed may be explained by YOY spottails feeding in or near the beach during the day. At night YOY move out beyond the 1.5-m depth contour. Price (1963) found that spottails in Lake Erie fed mostly in the morning with feeding activity decreasing throughout the day. Absence of YOY spottails from depths greater than 1.5 m suggests a preference by smaller spottails for shallower water. Wells and House (1974) noted that in Lakes Erie and Michigan, spottails preferred shallow, warm water and that smaller fish tended to inhabit shallower water than larger fish.

September--For reasons not entirely known (e.g., photoperiod, water temperatures, feeding behavior, etc.) spottail shiner densities seemed to increase with depth during September. Adults were the first to move offshore, while YOY spottails were concentrated in the beach zone. During September 1977, the largest YOY catch of any year (nearly 3900) was collected in beach seine hauls; nearly 80% of these were caught at north discharge beach station R. Warm water from the plant's onshore discharge apparently attracted

spottails to the north transect beach station. Water temperature at the north station was 15.6 C compared to 11.1 C at south reference beach station P. Schooling behavior may also have caused this large catch of YOY spottails. No YOY spottails were caught in trawls during September 1977.

Nearly half the spottail shiners collected in September 1978 were YOY fish 25-55 mm; 209 were caught in beach seines, 105 were trawled at the 9-m north transect station and 104 at the 3-m south transect station. These data suggest that, although YOY spottails were concentrated in 3 m of water or less, there was also a movement to deeper water as evidenced by the large catches at trawling stations. The seasonal movement to deeper water had begun by September in 1978.

The lowest September catch of YOY during the preoperational study occurred in 1979. Approximately 90 YOY spottails were seined at north transect beach stations; none were caught in trawls. Because cold water temperatures occurred during the 1979 spawning season (see RESULTS AND DISCUSSION, Spottail Shiner, Larvae), high egg and larval mortality and disrupted adult spawning behavior most likely resulted in low recruitment of YOY spottails in September 1979.

September 1980 catches were the second largest for that temporal period during the 4-yr preoperational study (Fig. 54). Trawls (mostly night) accounted for 381 YOY and day seines collected 644 (79 were seined at night). Trawl data indicated that YOY spottails were concentrated at 6 and 9 m. YOY spottails were consistently found in the beach zone during the day during all 4 yr. The large catch at 6 and 9 m indicated that the annual migration to deeper water was in its initial stages in September 1980.

Spawning and hatching apparently continued uninterrupted in 1980 which resulted in large numbers of YOY spottails being present in September 1980 collections. This is in contrast to the near absence of YOY from samples taken during the same period in 1979 when upwellings occurred during the spawning season.

October--October catches of YOY spottails during all years (Fig. 54) of the preoperational study were influenced by the annual fall migration of spottails to deeper water in Lake Michigan as was described by Wells (1968) and Jude et al. (1979a, 1979b). YOY spottails are nearly absent from the beach zone in October (Fig. 54). Never more than 52 YOY spottails were seined in October of any year, a drastic reduction from numbers of fish seined in September. In all years except 1980, few YOY spottails were caught in October and those caught were concentrated at 6 m and 9 m. The large year class of spottail shiners produced in 1980, possibly due to optimal water temperatures throughout the entire spawning period, is evidenced by October 1980 trawling data (Fig. 54). YOY spottails in large numbers (for October) were trawled at 6, 9, 12 and 15 m (116, 424, 182 and 200 fish, respectively). Because of warmer water temperatures during 1980 the migration to deeper water was most likely delayed and fish remained in the study area for a longer period of time than in other years.

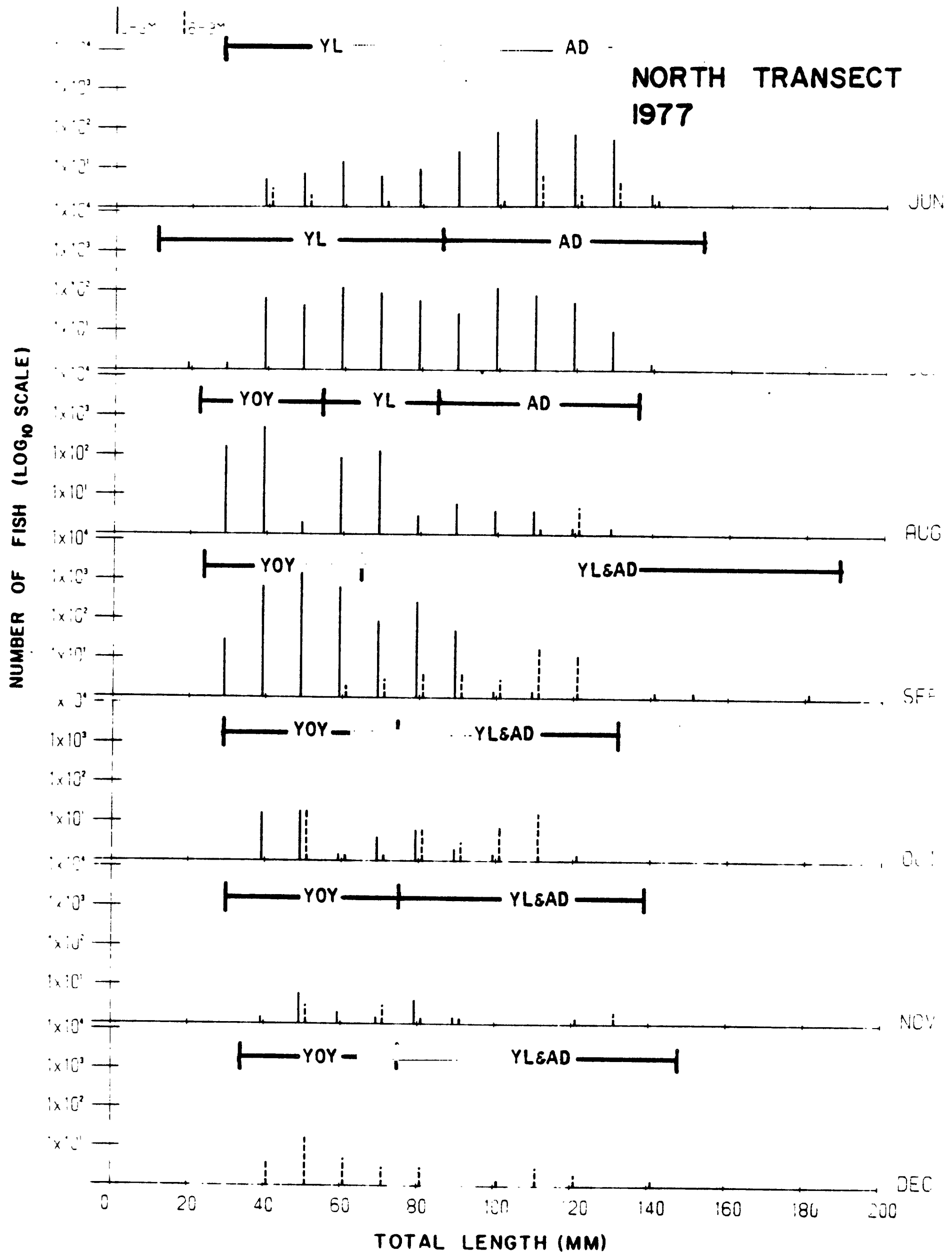
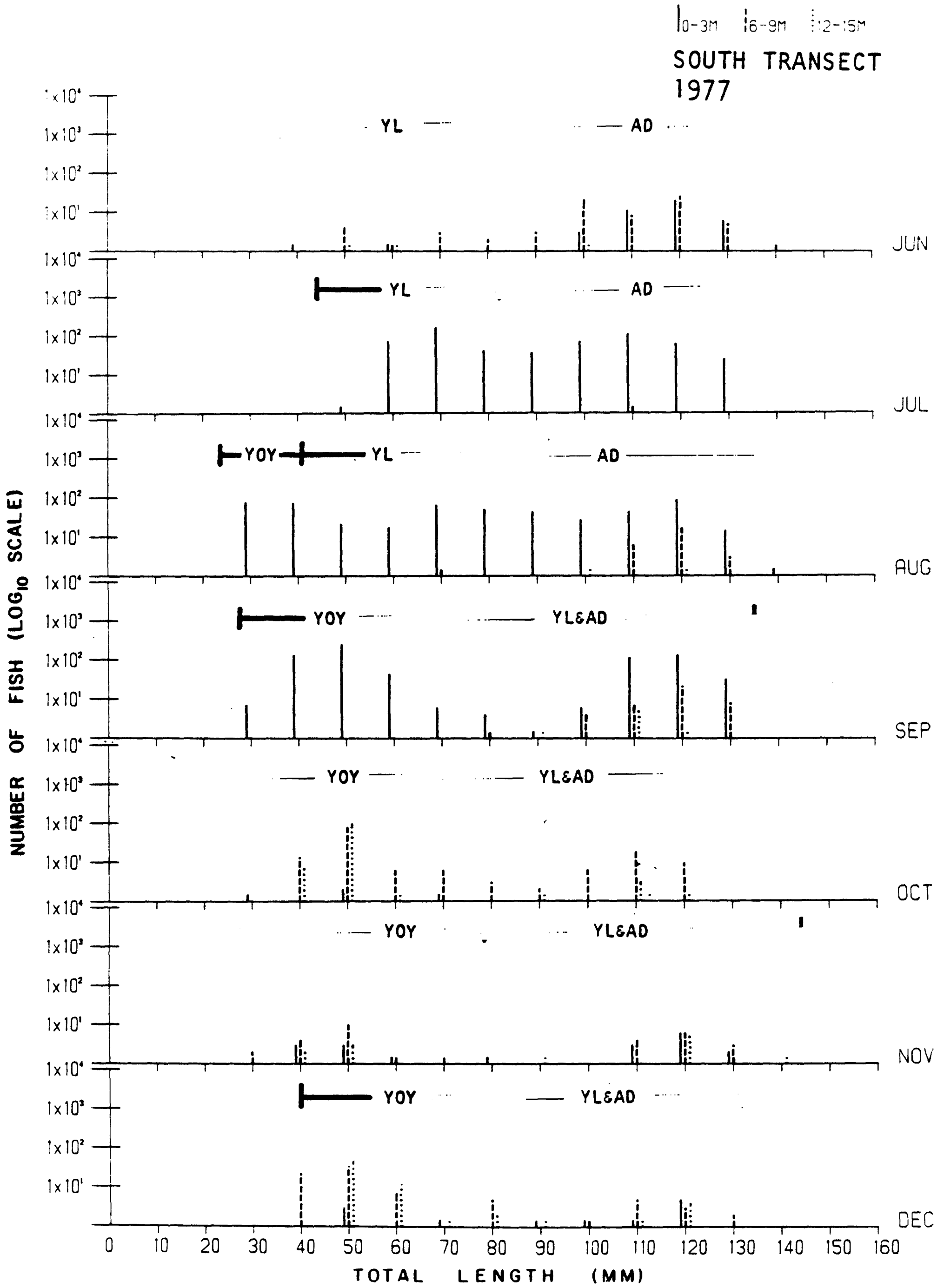


Fig. 54. Length-frequency histograms for spottail shiners collected during June - December 1977 and April - December 1978-1980 at north and south transects. Stations were combined into two groups for the north transect: beach and 3 m; 6 and 9 m and into three groups for the south transect: beach, 1.5 and 3 m; 6 and 9 m; and 12 and 15 m. Diel periods and gear types were pooled. YOY = Young-of-the-year; YL = Yearling; AD = Adult.



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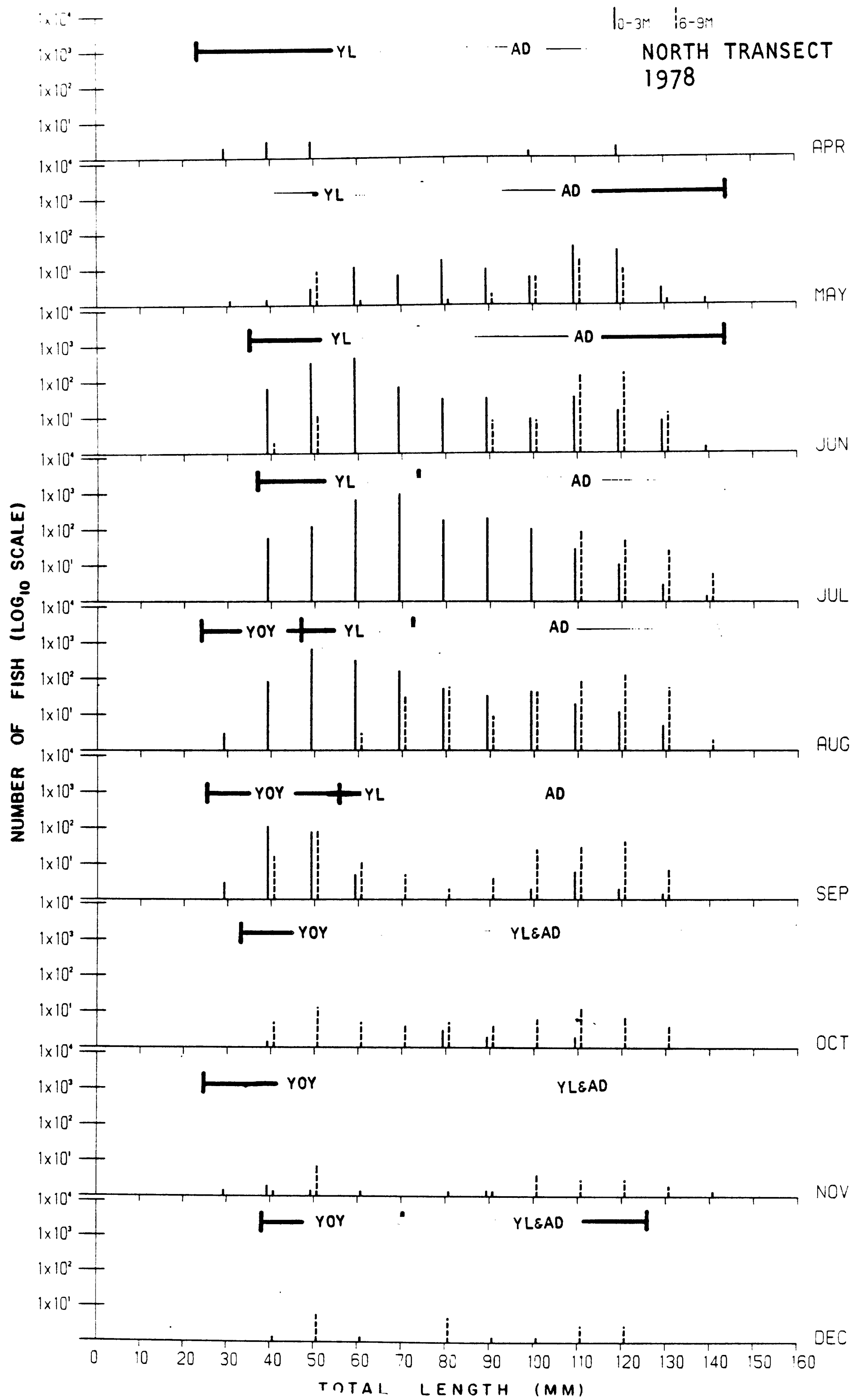

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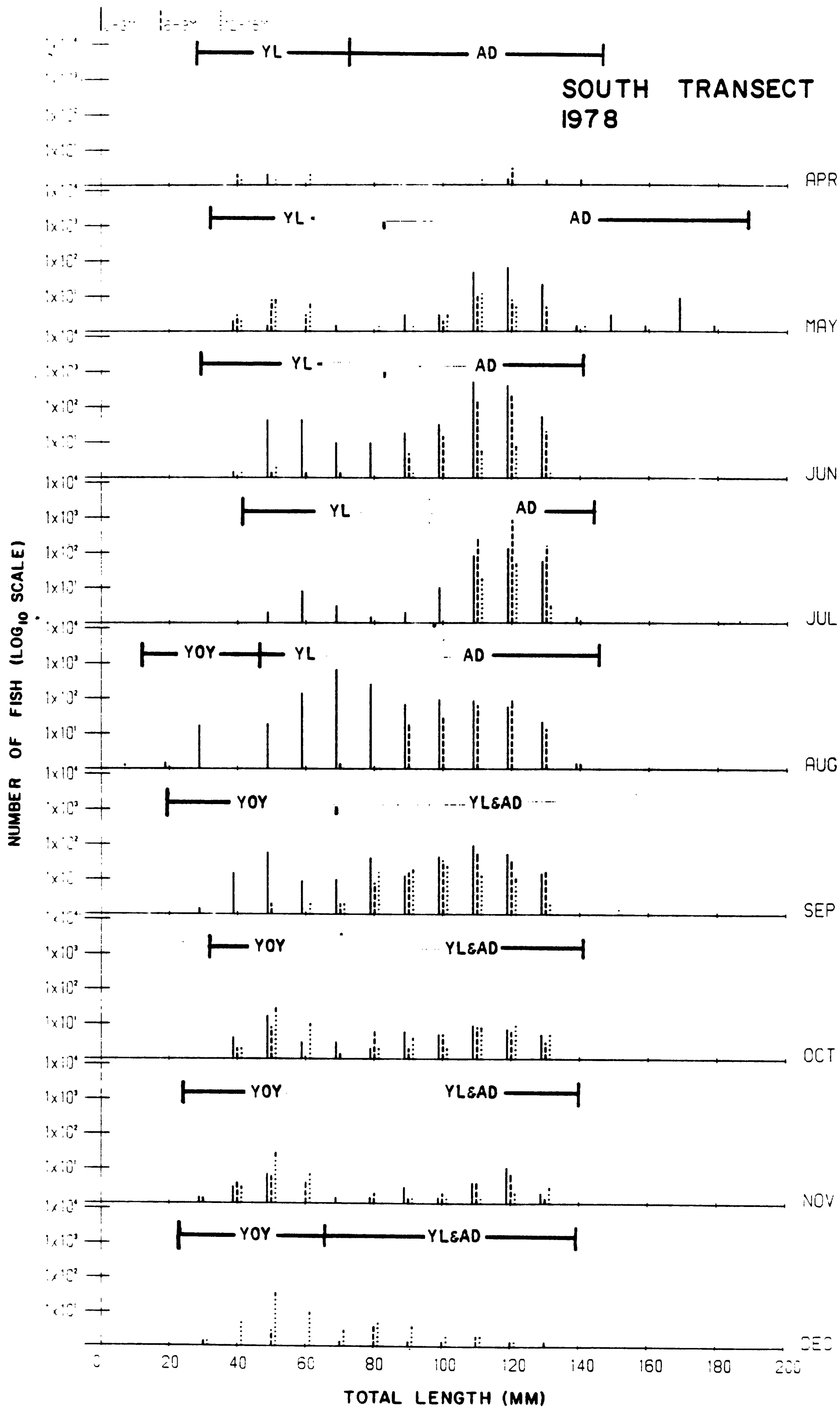

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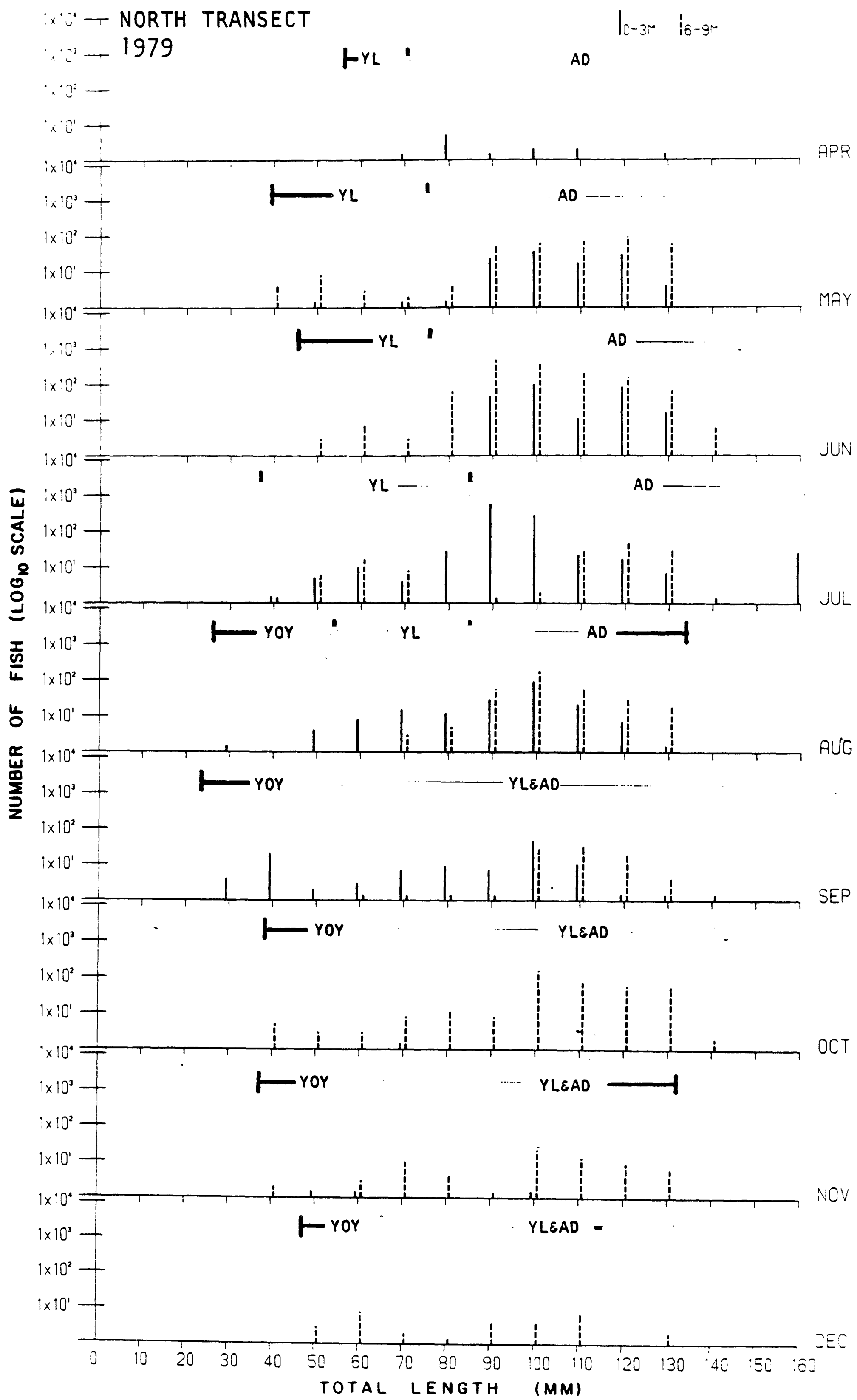

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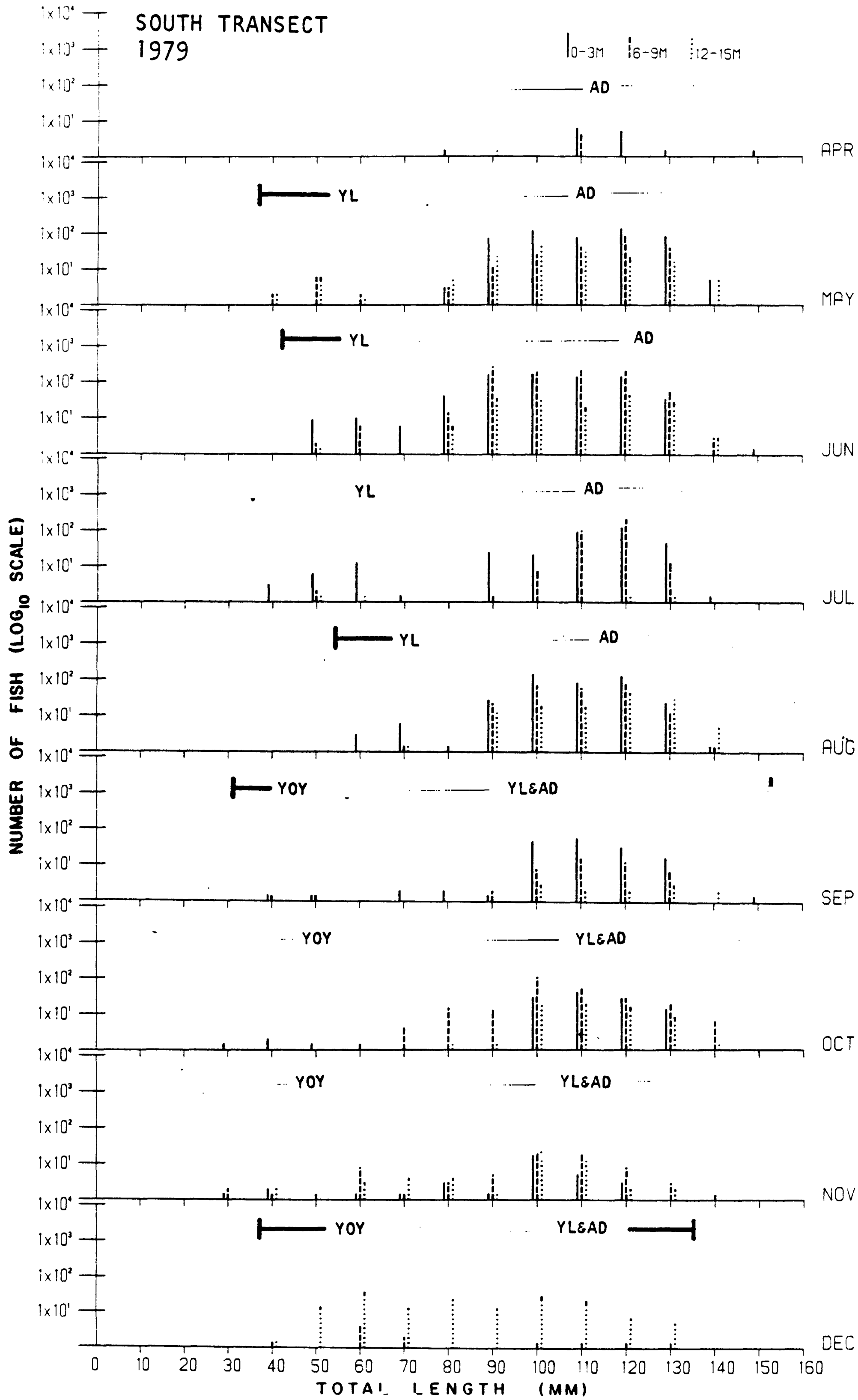

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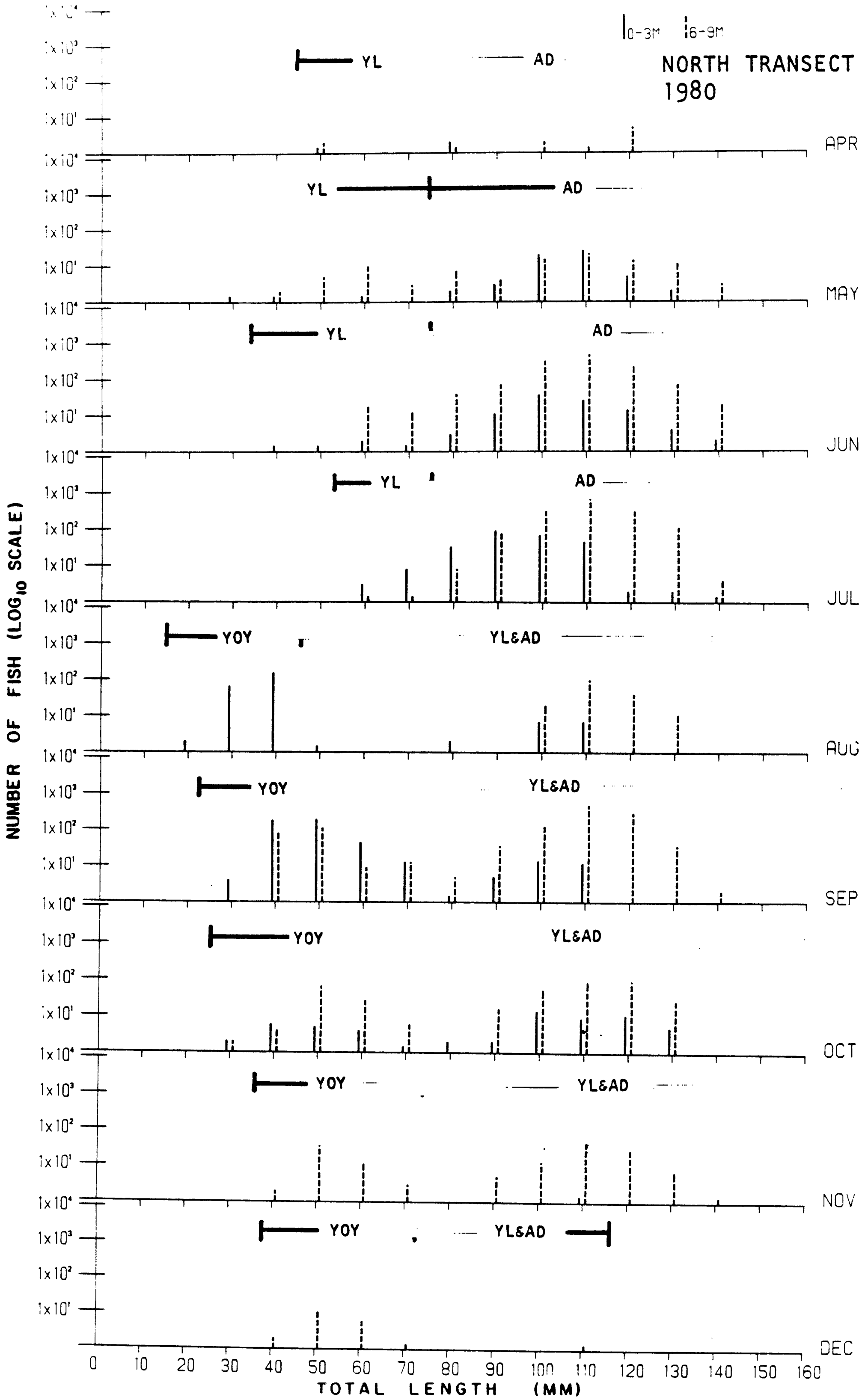

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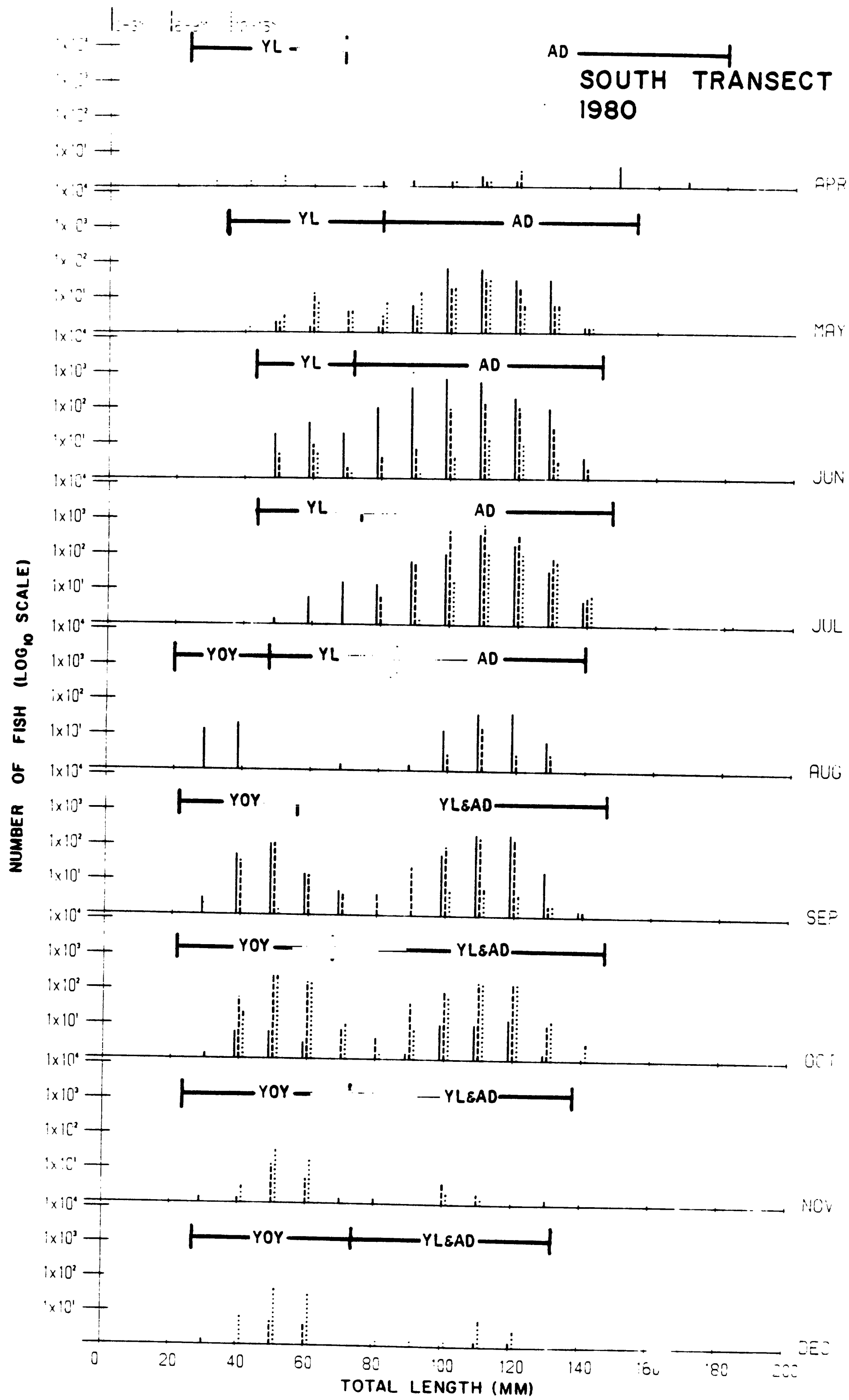


Fig. 54. Continued.

November and December--Catch data from November and December of all preoperational years showed that YOY spottails were the last group to migrate to deeper water. Two YOY were caught in the beach zone in November; most were at 9 m or deeper. December trawl data for all years showed that YOY spottails were present at 12 m and deeper. No unusual trends were apparent for YOY spottails during the November-December study period.

Adults--

Seasonal distribution--

April and May--Spottail shiners were collected in very low numbers during April 1978, 1979 and 1980. No sampling was performed during April 1977. The low density of spottail shiners in the study area during April is typical of their spring distribution in southeastern Lake Michigan. Wells (1968) found that spottails moved to shallower depths during summer (6-10 m) and deeper water (6-50 m) during winter. In Lake Michigan near the Campbell Plant the inshore migration began in May, as evidenced by the large numbers of large adults (85-135 mm) caught: 425, 1313 and 565, respectively, in 1978, 1979 and 1980. During May 1978, 1979 and 1980, densities of adult spottails were highest in the beach zone out to 6 m. Although sporadic catches occurred at all sampling depths, between 50 and 76% of the May adult spottail catch was collected from 6 m or less of water from 1978-1980 (Fig. 55).

June--By June, spottails have completed their movement to the inshore area. Most fish were found in 6 m of water or less, with sporadic occurrences out to 15 m. Gonad development data (Fig. 55) along with larval fish data (see RESULTS AND DISCUSSION, Spottail Shiner, Larvae) showed that spottail spawning occurred during June of all years. The distribution of ripe-running adults as well as newly hatched larvae and fish eggs strongly suggests spottails spawn in water 6 m or less. June adult spottail catch increased each successive year during the 4-yr study. Only 559 were caught in 1977 in contrast with 3083, 3442 and 3889 fish for 1978, 1979 and 1980 respectively. Night gill nets were not set in June 1977 resulting in less sampling effort for that year. During 1977 and 1978 beach seines and bottom gill nets caught most adult spottails with relatively few caught in bottom trawls. During those years north transect beach stations accounted for most of the fish caught in seine hauls. Warmer water temperatures at north transect beach stations than at the south transect beach station were most likely responsible for the catch difference among these stations (Fig. 22). In contrast to the low numbers of adult spottails caught in trawls during June 1977 and 1978, 70-72% of the June 1979-1980 catch was collected in bottom trawls. As would be expected most were trawled at night from 6-m contours or less. During June 1980 water temperatures were warmest at 3 m (14.5 C) and decreased with increasing depth (7.9 C at 15 m). Nearly one-half of the June 1980 trawl catch was taken at the 3-m south station. This large catch (1372 fish) was most likely due to warmer water and spawning activity. The lowest June beach seine catch of the entire study period occurred in 1980.

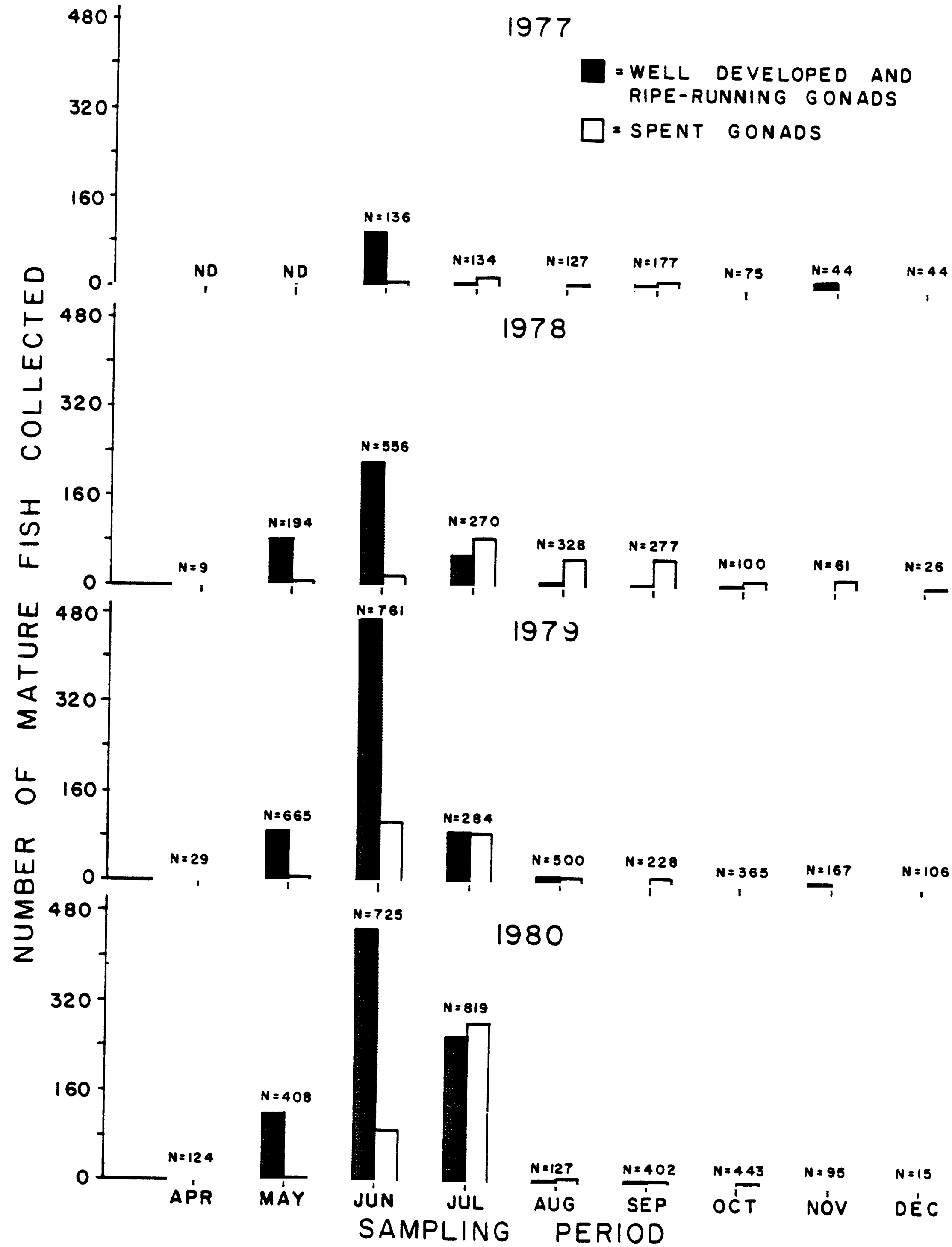


Fig. 55. Number of mature spottail shiners with well developed, ripe-running and spent gonads collected monthly during June-December 1977 and April-December 1978-1980 near the J. H. Campbell Plant, eastern Lake Michigan. N = total number of mature spottail shiners caught per month.

Some general trends observed during June of the preoperational study show that adult spottails are found almost exclusively from the beach zone out to 9 m with densities increasing with decreasing depth. Numbers of fish caught in beach seines were greater during the day, while bottom gill net and trawl samples were largest at night. Most of the adult spottails ranged in size from 100 to 135 mm.

July--The distribution of adult spottail shiners during July 1977, 1978 and 1979 was quite similar among years, being characterized by large numbers of fish in beach seine hauls, moderate bottom gill net catches (except 1977 when fishing time was reduced and a low catch resulted), and few caught in bottom trawls.

During July 1977, 97% of the catch was collected in beach seines. Night seine hauls at the south beach station contained the most fish, but moderate catches were also recorded at north transect beach stations. Very few spottails were caught in water deeper than 1.5 m in July 1977.

July was the month of peak abundance for spottails during 1978 with beach seines collecting 58% of the monthly total and bottom gill nets 41%. Few (<1%) were caught in trawls. Day seines at the north transect, where the water temperature was 19.0 C, contained the most spottails, while at the south beach station few spottails were caught and the water temperature was 16.0 C. The largest night catch in July 1978 was taken in bottom gill nets at the 9-m south station; these were all large adults 105-135 mm. Some small spottails (95-120 mm) were taken at 1.5- and 3-m south transect stations. Occurrence of ripe-running fish (Fig. 55) indicated that spawning was ongoing during July.

During July 1979 a diel activity pattern was observed in beach seine hauls where 98% of the catch was collected during the day. As in 1978 most of the catch was taken at north transect beach stations. Warmer water during the day at these stations (12.5 C in contrast to 10.5 C at night) and spawning activity may account for this diel catch difference. Anderson and Brazo (1978) reported finding high densities of spottails in the beach zone during the day in June in east central Lake Michigan. It is possible that spottails spawn primarily during the day in Lake Michigan. Bottom gill net catches during July 1979 were largest during the day and almost all spottails (89%) were caught in 6 m of water or less. These were large fish ranging in size from 105 to 135 mm. As in July 1977 and 1979, few spottails were trawled in July 1980 and gonad development data (Fig. 55) showed that spawning was occurring during this time.

The largest monthly catch of spottails in 1980 was taken in July. In contrast to the July catches of 1977-1979, when the majority of the catch was seined and few were trawled, 47% of the July 1980 catch was collected in bottom trawls, while less than 1% was caught in beach seines. The remainder of the fish were taken in bottom gill nets. Mostly large fish were collected; size range was 105-145 mm. Trawl data showed that spottails were concentrated at 6 and 9 m during July 1980; 79% of the trawled fish were caught there. Trawl catches were nearly equal during day and night. Bottom gill net catches showed a nocturnal activity pattern with 77% of the spottails caught at night.

Largest catches were at 6 m with moderate numbers of fish caught at 1.5, 3 and 9 m. Very few spottails were gillnetted at 12 m. Isothermal waters during July 1980 were most likely responsible for the difference in catch during this year, in contrast to the first 3 yr of the preoperational study, when periods of upwellings tended to concentrate spottails in the warmest water in the study area. However, in July 1980, the mean water temperature from the beach to 9 m was 21.0 C and the fish moved throughout this zone, while avoiding cooler waters at 12 and 15 m (mean temperature of 18.1 C). Gonad development data (Fig. 55) showed that spottails spawned during July 1980; lack of upwellings during 1980 should produce a strong year class in 1981 and 1982.

August--By mid-August, when sampling was performed, spottail shiner spawning was completed in the study area and large adults were dispersed throughout the area. As spawning ceased in late July or early August (Fig. 55), fewer adults were found at beach stations. During August of all 4 yr of the study, adults were randomly distributed throughout the study area with peak catches occurring anywhere between 1.5 and 15 m; a decline in total number of fish caught in August was observed in 1979 and 1980. Because water temperatures were usually quite stable in August and spawning was complete, spottails may have moved about the lake much more than during other months. During 1979 and 1980 spottails were more dispersed than in 1977 and 1978 which apparently resulted in the lower August catches observed.

September--During September 1977 few adult spottails were in the beach zone as evidenced by their absence from beach seine hauls. Day and night trawl hauls caught few adult spottails. Bottom gill net data showed adult spottails at 1.5 to 6 m during the day, with largest catches at 1.5 and 3 m. At night spottails extended their depth range out to 12 m and probably deeper (few were trawled at 15 m).

September 1978 beach seine hauls contained no adult spottails, while bottom gill net data showed concentrations at 1.5 and 6 m during the day. Night bottom gill nets showed a scattering of adults throughout the study area, with the largest catch at 12 m and some at 15 m. Few adult spottails were trawled in September 1978. Bottom gill nets accounted for the largest catch of adult spottails in September 1979 (217 fish); 83% were caught at 6 m or less. No adults were seined in September 1977-1980 and few were caught in bottom trawls in 1977-1979. The largest catch of adult spottails in September for the entire study period occurred in 1980 (Fig. 54). Apparently the annual fall migration to deeper water by spottails, as described by Jude et al. (1978, 1979a), Anderson and Brazo (1978) and Wells (1968) had not yet begun to any substantial degree by mid-September 1980. The stable water temperatures noted all year in 1980 (i.e., no upwellings) may have prolonged spottail use of the study area. In contrast to the period 1977-1979, when few adults were trawled in September, moderate numbers of adult spottails were trawled during September 1980 (853 fish). Nearly 93% of these fish were trawled at 9 m, while the remainder were trawled at 6 m; only a few were trawled deeper than 9 m. Bottom gill net data showed concentrations of adult spottails at 3 and 6 m with largest catch (444 fish) at 3 m.

Generally during September, adult spottails were absent from the beach zone and were often concentrated between 3 and 9 m of water. The annual fall migration to deeper water usually begins by mid-September. Climatic conditions of the preceding summer may be a determining factor in triggering the migration to deeper water in the study area.

October--In October 1977-1979 no adults were caught in beach seines or day trawls. At night some smaller adults (95-145 mm) were trawled at 6 and 9 m. Gill nets were not set in October 1977. Eighty-three percent of the modest bottom gill net catch (53 fish) in October 1978 was caught at 6 m or deeper. Bottom gill net catches showed larger adults (110-145 mm) uniformly distributed among 1.5- to 15-m stations. The largest catch (60 fish) was taken at 6 m north. Water temperatures in October 1979 were nearly the same as September (11.0-13.5 C), resulting in a delay of the annual migration to deeper water by all adult spottails.

A few adult spottails were seined at north beach stations in October 1980 when water in the study area was nearly isothermal (9.5-11.5 C). All seined fish were caught at night and may have moved in to forage for food. Trawl data showed concentrations of adults at 6 and 9 m with lesser numbers of adults at 3, 12 and 15 m. Bottom gill net catches showed that adult spottails were absent from the study area during the day, while at night adult fish were concentrated at 6, 9, 12 and 15 m with the largest catch at 12 m.

In general during October adult spottails were absent from the beach zone and may have migrated from the study area as was observed in 1977 and 1978. When climatic conditions remained stable from September into October, as observed in 1979 and 1980, adults may remain in the study area for a longer period of time.

November and December--Catches of adult spottails decreased dramatically in November and December of all years of the study. Sporadic catches of small adults (100-130 mm) occurred throughout the study area in November and at 12 and 15 m in December. By mid-November the majority of the adult spottail population had migrated out beyond the 15-m depth contour. The largest adults were the first to leave, followed by smaller adults, yearlings and YOY spottails.

Plant Effects--

The primary difficulty in assessing the impact of Units 1 and 2 on spottail shiner distribution is our inability to dismiss coincident construction activity as a probable cause of reference and treatment area differences. Both the timing of construction activity and resulting riprap placement strongly correlate with significant changes in trends observed since 1977, however, there are a few anomalies to this general scheme. During 1977, when the discharge of Units 1 and 2 was onshore, no significant abundance differences between north and south transects existed for either larval or juvenile spottail shiners, except for abundance of juvenile and adult spottail shiners based on seine data. Abundance at the beach station group (Q, R) at the plant transect was significantly greater than that at reference station P;

this transect difference was fairly consistent for years 1977 through 1980 (Fig. 56, Table 31). Bottom gill net data for juvenile and adult spottail shiners showed no significant differences between stations (or areas) for years 1977 through 1980 (Fig. 56, Tables 32-34). However, trawl data showed significantly greater abundance at the north plant transect than at the south transect (Fig. 57, Tables 35 and 36). Substantially higher abundance of juvenile and adult spottail shiners was observed at the plant transect during 1979 and 1980, coincident with construction activity (Fig. 57). During 1979-1980 larval abundances were significantly higher at north transect stations compared with the south reference transect, as revealed by a Wilcoxon signed ranks test (attained significance level $\alpha = 0.0011$ and 0.0006 respectively). Our data thus indicate that, especially during 1979 and 1980, when riprap was being constructed and was available to varying degrees, all age-groups of spottail shiners were more abundant along the north transect.

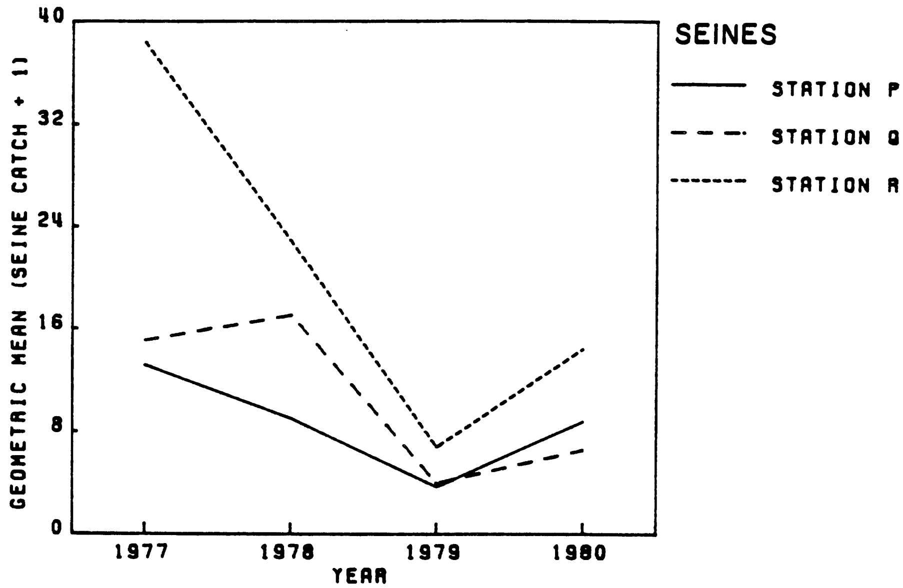
Reasons for greater abundance of spottails at the north transect are unknown; however, two obvious correlations exist. The construction itself may have provided increased food by displacing benthic organisms during dredging. The concentration of adults in the area coincident with their spawning season may have also resulted in a concentrated spawning effort there. This is substantiated in part by our larval spottail comparisons which show that north transect spottail larvae densities significantly exceeded those of the south transect during 1979 and 1980 (attained significance level $\alpha = 0.0011$ and 0.0006 respectively). In addition, Dorr and Miller (1975) have documented spottail spawning on the riprap around the Cook Plant intake structures, which are located in 9 m of water. Another attractive influence of the intake and discharge area may be the riprap itself. It is possible that the riprap attracted spawning adults to the area, especially in 1979 and 1980, due to a preference for increased cover or food. In all years we could find no temperature correlation to explain distributional or abundance differences between the north and the south transect. We thus feel that no definitive statements regarding the influence of the thermal plume of Units 1 and 2 on spottail shiner distribution or abundance can be made. If the riprap remains exposed and if it has an attractive influence on spottail shiners, we would expect increased numbers of spottails in the north transect area. This may preclude definitive statements of thermal effect in the future and make tenuous the validity and utility of only 1 additional yr of study.

<u>Trout-perch</u>

Introduction--

Trout-perch inhabit all the Great Lakes and a few of the larger inland lakes (Hubbs and Lagler 1958). In Lake Michigan this species occurs most commonly in shoal areas, but may range into water as deep as 94 m (House and Wells 1973). This species is considered benthic as most fish are caught near or at the lake bottom. Most trout-perch mature at age 2, although our data and other sources (House and Wells 1973; Magnuson and Smith 1963; Kinney 1950) show some yearlings are sexually mature.

SPOTTAIL SHINER



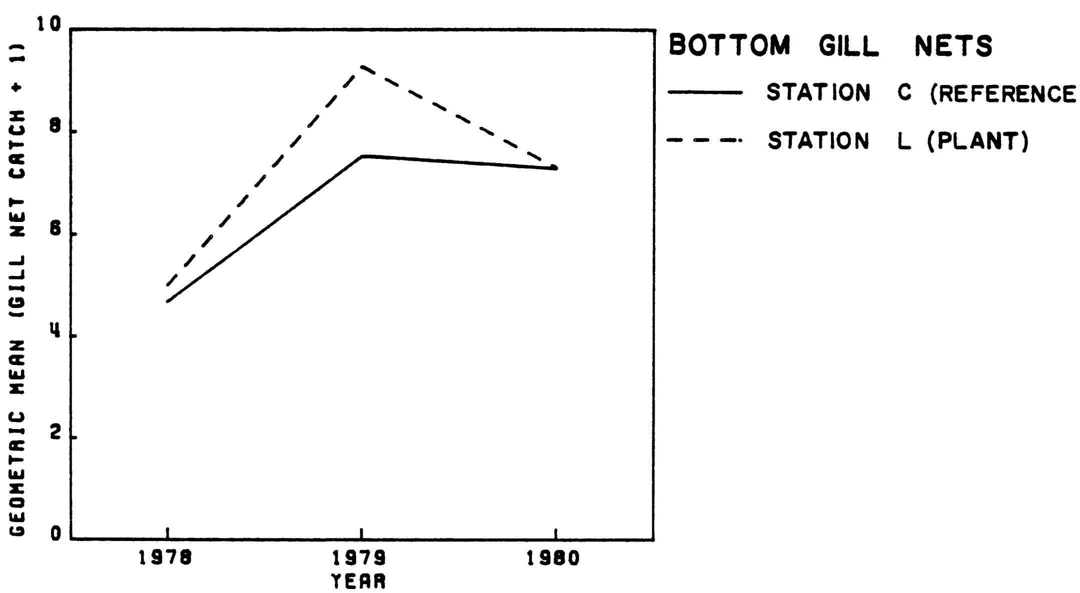


Fig. 56. Geometric mean number plus one of spottail shiners caught in seines at beach stations P (south reference), Q (south discharge) and R (north discharge) and in bottom gill nets at stations C (6 m, south) and L (6 m, north) near the J. H. Campbell Plant, 1978 through 1980. Graphs illustrate the YEAR X STATION interaction.

Trout-perch was consistently one of the most common fish species in Lake Michigan in the vicinity of the Campbell Plant from 1977 through 1980. Trout-perch comprised approximately 1.1% of the total adult and juvenile catch in Lake Michigan in 1977, slightly more than 2% of the catch in both 1978 and 1979 and about 3.5% of the catch in 1980. Catch of trout-perch adults and juveniles over the years 1977 through 1980 totaled 7374 fish. About 35% (2600 individuals) of this total was comprised of yearlings and about 64% (4727 individuals) of these fish were adults (age 2 or older); a few YOY (47 fish) were also caught. All YOY and over 90% of the yearlings and adults were caught in trawls; remaining adults were caught in seines or gill nets, while the rest of the yearlings were seined.

Larvae--

Although trout-perch yearlings and adults were very common, trout-perch larvae were relatively uncommon in the study area. The trout-perch is not a very prolific spawner and has relatively low fecundity, which undoubtedly partially explains the low catch of larval trout-perch. Egg counts per female performed by Lawler (1954) ranged from 240 to 728 with a mean of 349. A prolonged spawning season for trout-perch may also contribute to relatively low larvae densities of this species. Trout-perch larvae apparently are demersal; of the 44 specimens collected during 1977 through 1980, 37 (or about 84%) were collected in sled tow samples. These larvae were apparently not susceptible to the majority of our sampling gear. Larvae were mainly collected at depth contours of 6 m or deeper; only seven were collected inshore (beach to 3 m).

The first 2 yr of sampling effort (1977-1978) yielded only five trout-perch larvae from Lake Michigan. In 1979, 11 larvae were collected, while in 1980 28 were taken. The higher incidence of larval trout-perch in 1979 and 1980 may be related to construction activity as well as the resultant riprap structures providing suitable spawning habitat.

In 1977 three larvae were collected, all with the sled. A 15-mm specimen was caught at station F (15 m, south) in late July. A 6-mm larva was caught at station J (3 m, north) and a 10-mm one at station L (6 m, north), both during September 1977. Jude et al. (1979b) and Fish (1932) reported the length of hatching of trout-perch to be between 5.5 and 6.0 mm. Eggs hatch in a few days after fertilization (Scott and Crossman 1973). Thus in 1977 trout-perch were still spawning in the study area during September. In 1978 two larvae were collected in Lake Michigan: a 6.8-mm larva at station W (15 m, north) in late August and a 6.0-mm larva at station B (3 m, south) in September. Appearance of this newly hatched trout-perch indicates trout-perch spawning extended into September of 1978 as well.

In 1979 two trout-perch larvae were captured in April (each between 6 and 7 mm TL); one occurred at the south transect beach station and one was found at station D (9 m, south). In early August three larvae (7.5 to 12.8 mm) were caught at station L (6 m, north), and a 5.7-mm larva was captured at station E

Table 31. Analysis of variance summary for spottail shiners caught in seines at stations P (south reference), Q (south discharge) and R (north discharge) near the J. H. Campbell Plant, eastern Lake Michigan, 1977 through 1980. Data for June through November were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	3	4.5163	22.9732	<0.0001**
Month	4	8.1834	41.6263	<0.0001**
Station	2	2.5752	13.0994	<0.0001**
Time	1	0.0744	0.3787	0.5395
Y x M	12	1.6998	8.6463	<0.0001**
Y x S	6	0.1885	0.9591	0.4560
M x S	8	0.9195	4.6775	0.0001**
Y x T	3	0.0942	0.4793	0.6973
M x T	4	1.5958	8.1175	<0.0001**
S x T	2	0.0806	0.4099	0.6646
Y x M x S	24	0.6206	3.1580	<0.0001**
Y x M x T	12	1.8110	9.2122	<0.0001**
Y x S x T	6	0.5325	2.7087	0.0168
M x S x T	8	0.5808	2.9544	0.0047*
Y x M x S x T	24	0.4537	2.3077	0.0016*
Within cell error	120	0.1966		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

Table 32. Analysis of variance summary for spottail shiners caught in bottom gill nets at stations C (6 m, south) and L (6 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1977 through 1980. Data for July through September and November were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	3	2.0248	39.4046	<0.0001**
Month	3	2.1267	41.4259	<0.0001**
Station	1	0.2834	5.5147	0.0220
Time	1	9.2305	179.6337	<0.0001**
Y x M	9	0.8959	17.4341	<0.0001**
Y x S	3	0.5269	10.2533	<0.0001**
M x S	3	0.1464	2.8481	0.0444
Y x T	3	1.0723	20.8680	<0.0001**
M x T	3	0.1874	3.6469	0.0171
S x T	1	0.0062	0.1198	0.7303
Y x M x S	9	0.4005	7.7943	<0.0001**
Y x M x T	9	1.7038	33.1580	<0.0001**
Y x S x T	3	0.1215	2.3651	0.0792
M x S x T	3	0.2504	4.8734	0.0041*
Y x M x S x T	9	0.4015	7.8130	<0.0001**
Within cell error	64	0.0514		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

Table 33. Analysis of variance summary for spottail shiners caught in bottom gill nets at stations C (6 m, south) and L (6 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1978 through 1980. Data for May through October were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	2	0.7443	13.3854	<0.0001**
Month	5	1.6924	30.4347	<0.0001**
Station	1	0.0556	0.9994	0.3208
Time	1	18.0707	324.9602	<0.0001**
Y x M	10	0.8651	15.5572	<0.0001**
Y x S	2	0.0257	0.4625	0.6315
M x S	5	0.4105	7.3811	<0.0001**
Y x T	2	0.4403	7.9170	0.0008**
M x T	5	0.7529	13.5399	<0.0001**
S x T	1	0.0322	0.5794	0.4490
Y x M x S	10	0.4300	8.6323	<0.0001**
Y x M x T	10	2.2130	39.7958	<0.0001**
Y x S x T	2	0.0389	0.6998	0.5000
M x S x T	5	0.2474	4.4493	0.0014*
Y x M x S x T	10	0.3387	6.0909	<0.0001**
Within cell error	72	0.0556		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

Table 34. Analysis of variance summary for spottail shiners caught in bottom gill nets at stations C (6 m, south), D (9 m, south), L (6 m, north) and N (9 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1980. Data for May through October were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Month	5	2.7195	47.8277	<0.0001**
Area	1	0.0689	1.2115	0.2765
Depth	1	1.1206	19.7076	0.0001**
Time	1	10.1230	178.0341	<0.0001**
M x A	5	1.0045	17.6657	<0.0001**
M x D	5	0.5675	9.9815	<0.0001**
A x D	1	0.0658	1.1580	0.2873
M x T	5	0.7420	13.0499	<0.0001**
A x T	1	0.0420	0.7380	0.3946
D x T	1	0.0512	0.8996	0.3476
M x A x D	5	0.0798	1.4033	0.2400
M x A x T	5	0.1542	2.7114	0.0309
M x D x T	5	0.2982	5.2445	0.0006**
A x D x T	1	0.0014	0.0242	0.8771
M x A x D x T	5	0.2731	4.8029	0.0012*
Within cell error	48	0.0569		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

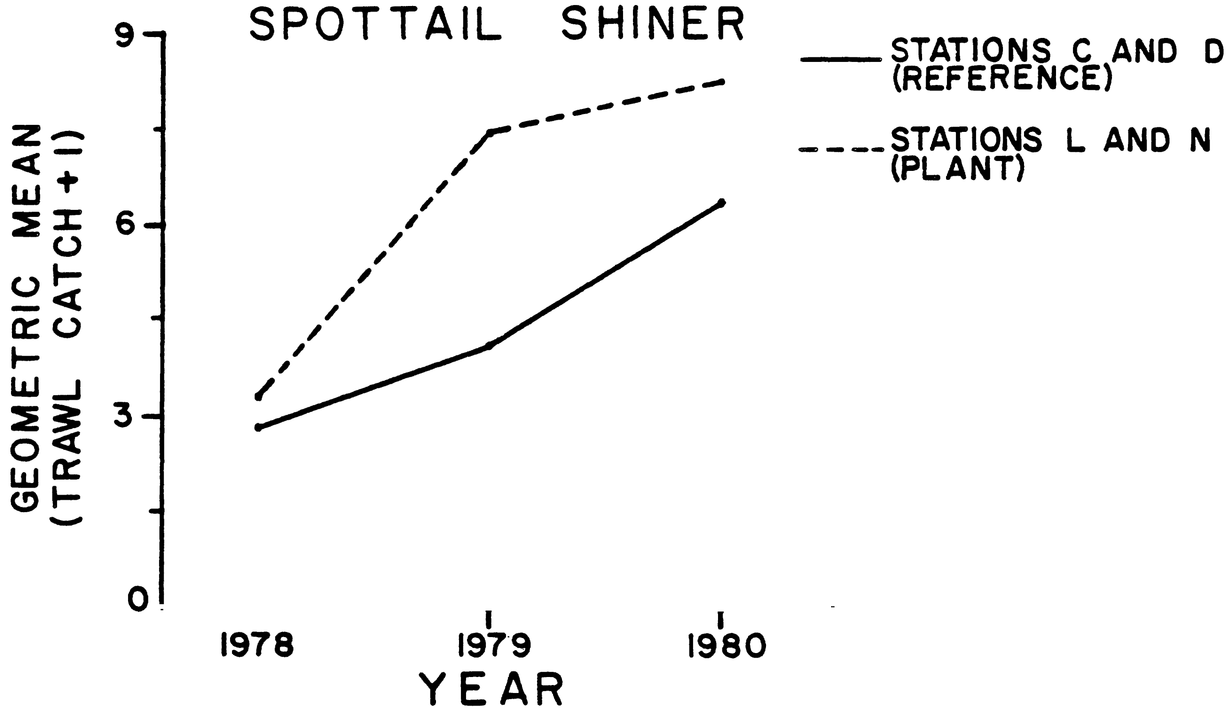


Fig. 57. Geometric mean number plus one of spottail shiners caught in trawls at stations C (6 m, south), D (9 m, south), L (6 m, north) and N (9 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1978 through 1980. Graph illustrates the YEAR x AREA interaction.

(12 m, south). Five larvae, ranging in length from 6.8 to 19.0 mm, were identified in samples from September 1979: one at the south transect 9-m station and one each at 3, 9, 12 and 15 m on the north transect.

In 1980 10 larvae (7.5 to 9.5 mm TL) were collected during early July in sled tows from 6 to 15 m along the north transect. In late July six larvae (6 to 14 mm) were captured at 6- to 9-m contours at the north transect. Eight trout-perch larvae (lengths of 6.2 to 20 mm) were identified in early August samples from 6 to 12 m from both transects. In late August one larva (7.0 mm) was collected from station A (1.5 m, south) and a 7.0-mm specimen from station B (3.0 m, south). A 10-mm specimen was collected from beach station Q (south of discharge) and an 8.5-mm larva was collected from station B; both were caught in sleds in September. As for 1977 through 1979, larvae data for 1980 indicate the spawning season for trout-perch extended through late August and probably early September. Densities of trout-perch larvae in Lake Michigan ranged from 8 to 337 individuals/1000 m³ for the years 1977 through 1980. Trout-perch larvae appear to be avoiding sampling gear during the day as only 6 larvae were caught during the day while 38 larvae were caught at night.

Table 35. Analysis of variance summary for spottail shiners caught in trawls at stations C (6 m, south) and L (6 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1977 through 1980. Data for June through December were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	3	1.3414	22.9666	<0.0001**
Month	6	1.9620	33.5935	<0.0001**
Station	1	1.9105	32.7109	<0.0001**
Time	1	33.1955	568.3696	<0.0001**
Y x M	18	1.8135	31.0513	<0.0001**
Y x S	3	0.2255	3.8608	0.0114
M x S	6	0.0750	1.2848	0.2700
Y x T	3	0.5961	10.2058	<0.0001**
M x T	6	2.0880	35.7500	<0.0001**
S x T	1	0.2809	4.8095	0.0304
Y x M x S	18	0.1645	2.8171	0.0005**
Y x M x T	18	0.4901	8.3912	<0.0001**
Y x S x T	3	0.0241	0.4129	0.7441
M x S x T	6	0.0477	0.8174	0.5586
Y x M x S x T	18	0.1179	2.0193	0.0139
Within cell error	112	0.0584		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

Thirty-three of the 44 trout-perch larvae were collected from the north transect. The Wilcoxon signed ranks test for larval density data for 1980 showed a tendency for densities of trout-perch larvae at the north transect to be higher than those at the south transect; this difference in densities between transects was significant at $\alpha = .05$ (the attained significance level for the test was .0229). Trout-perch may have been attracted to the riprap for spawning and thus larvae were more concentrated along the north transect than at the south transect. Most riprap was deposited by the close of the 1979 season.

In summary, trout-perch larvae are relatively uncommon in the study area. They were collected from April to September, with most being caught in June and July. They were collected mostly in water 6 m deep or deeper and almost all were caught in sleds. Larvae apparently are benthic. More were caught in 1980 than any other year. More trout-perch larvae were caught at the north transect than at the south transect.

Although no fry were collected in 1977 or 1978, 21 trout-perch fry (30-57 mm) were captured during 1979 and 1980 in Lake Michigan. All but one of these fry were caught in sled tows (one was caught in a plankton net towed near

Table 36. Analysis of variance summary for spottail shiners caught in trawls at stations C (6 m, south), D (9 m, south), L (6 m, north) and N (9 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1978 through 1980. Data for May through December were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	2	4.8385	61.5432	<0.0001**
Month	7	2.0410	25.9607	<0.0001**
Area	1	1.9598	24.9282	<0.0001**
Depth	1	0.4217	5.3642	0.0216
Time	1	60.6212	771.0713	<0.0001**
Y x M	14	2.8509	36.2619	<0.0001**
Y x A	2	0.3047	3.8757	0.0224
M x A	7	0.0526	0.6687	0.6984
Y x D	2	0.7045	8.9614	0.0002**
M x D	7	0.3867	4.9192	<0.0001**
A x D	1	0.6874	8.7431	0.0035*
Y x T	2	0.5597	7.1188	0.0010*
M x T	7	2.4579	31.2633	<0.0001**
A x T	1	0.3091	3.9314	0.0488
D x T	1	0.7413	9.4295	0.0024*
Y x M x A	14	0.2295	2.9196	0.0005**
Y x M x D	14	0.5620	7.1478	<0.0001**
Y x A x D	2	0.1741	2.2141	0.1120
M x A x D	7	0.0465	0.5915	0.7624
Y x M x T	14	0.4619	5.8749	<0.0001**
Y x A x T	2	0.0119	0.1518	0.8593
M x A x T	7	0.1915	2.4355	0.0206
Y x D x T	2	0.5335	6.7860	0.0014*
M x D x T	7	0.8882	11.2980	<0.0001**
A x D x T	1	0.0234	0.2978	0.5859
Y x M x A x D	14	0.2452	3.1185	0.0002**
Y x M x A x T	14	0.2312	2.9413	0.0004**
Y x M x D x T	14	0.4661	5.9279	<0.0001**
Y x A x D x T	2	0.0082	0.1042	0.9011
M x A x D x T	7	0.1888	2.4016	0.0223
Y x M x A x D x T	14	0.0664	0.8445	0.6202
Within cell error	192	0.0786		

** Highly significant ($P < 0.001$).
* Significant ($P < 0.01$).

bottom). These fry were all yearling trout-perch. All were caught between May and late July. Densities ranged from 17 to 133 fry per 1000 m^3. These "fry" yearlings were not included in any yearling catch statistics.

Young-of-the-Year--

A few YOY trout-perch have been caught each year from 1977 to 1980 (Fig. 58); all were caught in bottom trawls from August through November. Catch varied from 3 in 1979 to 16 in 1980. Since YOY trout-perch move offshore during the summer (Magnuson and Smith 1963), it is likely that most YOY had already entered offshore water (outside the study area) by the time they grew to a size at which they were susceptible to the trawl.

First occurrence of YOY trout-perch during our 1977 study was in September when nine (15-44 mm) were caught in water 9 to 15 m at the south transect (Fig. 58). The following month two YOY trout-perch (15-34 mm) were trawled at station F (15 m, south) and in November 1977 another three (15-34 mm) were caught at station E (12 m, south). Similarly in 1978, nine YOY (15-24 mm) were trawled in September from deeper water stations (9 to 12 m) at the south transect. That same year in October two YOY (15-34 mm) were caught at station F (15 m, south) and in November three (25-34 mm) were caught at the 9- to 12-m contours at the south reference transect.

In 1979 only three YOY trout-perch were collected; all three (25-44 mm) were caught at station F (15 m, south) in October (Fig. 58). Growth of YOY in 1979 may have been slower than in other years of the study because of the major upwellings during July; YOY may not have been susceptible to the trawls until October.

In 1980 YOY were collected as early as August when six specimens (15-34 mm) were caught: one at station C (6 m, south), one at station D (9 m, south) and four at station N (9 m, north) (Fig. 58). Growth of YOY was probably more rapid during July and August in 1980 than during those 2 mo in any other year, since there were no upwellings observed during those months in 1980, unlike the 3 previous yr. In September 1980 another eight YOY (25-44 mm) were trawled from 9- to 15-m deep water. In October, another two YOY (35-44 mm) were captured: one at station E (12 m, south) and one at station F (15 m, south).

All YOY trout-perch were collected at night. These fish may be effectively avoiding the net during the day.

Yearlings--

Yearlings comprised a substantial portion of the total number of trout-perch collected; over 35% (or 2598 fish) of the 7374 specimens caught during 1977 through 1980 were yearlings. Growth of yearlings was analyzed by examining length-frequency data through the year.

<u>Seasonal distribution</u>--

April--During 1978 and 1980 yearlings (15-74 mm) were collected in the study area as early as April. Three yearlings were caught in April 1978 and in April 1980, four yearlings were collected.

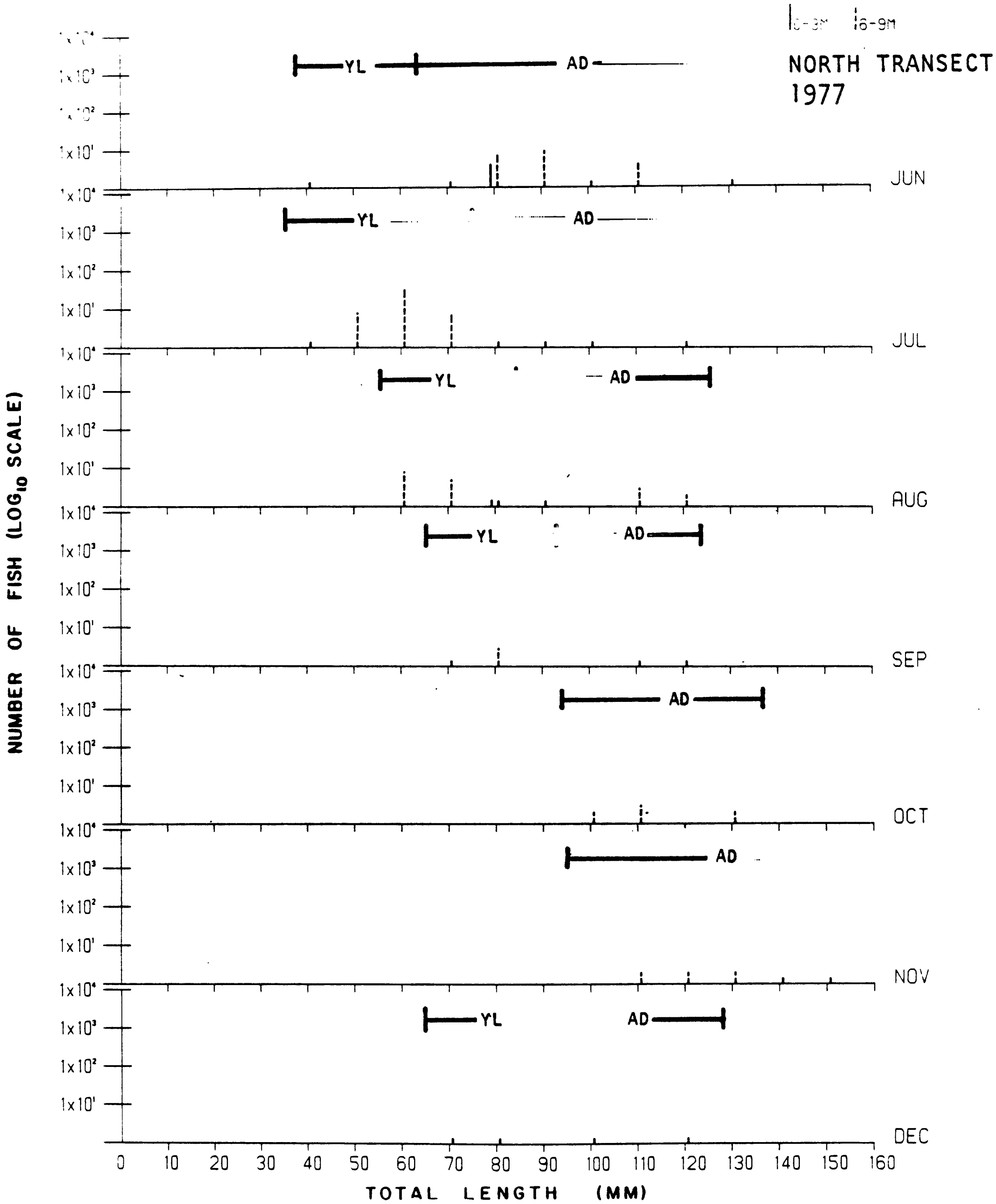


Fig. 58. Length-frequency histograms for trout-perch collected during June - December 1977 and April - December 1978-1980 at north and south transects. Stations were combined into two groups for the north transect: beach and 3 m; 6 and 9 m and into three groups for the south transect: beach, 1.5 and 3 m; 6 and 9 m; and 12 and 15 m. Diel periods and gear types were pooled. YOY = Young-of-the-year; YL = Yearling; AD = Adult.

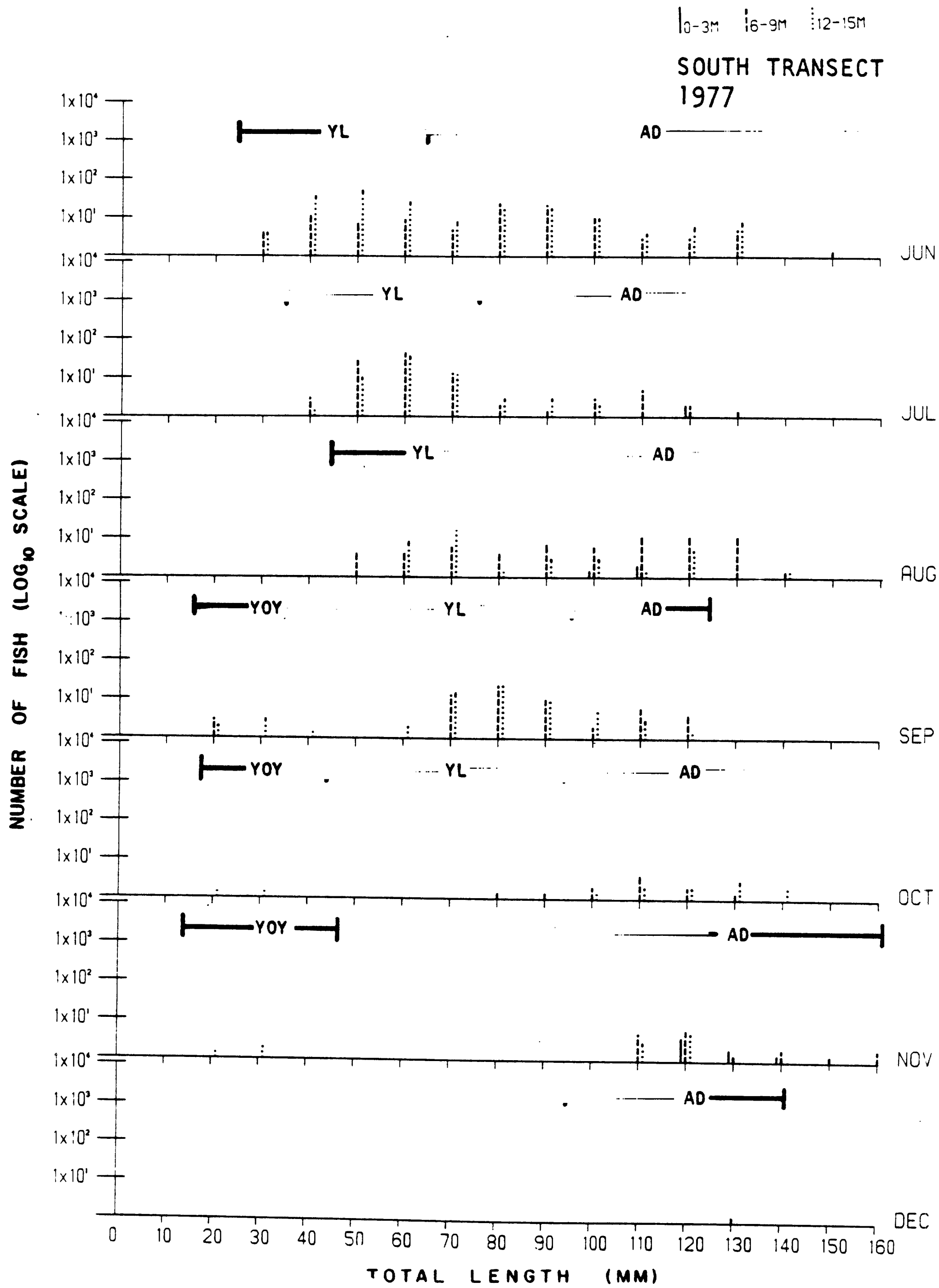


Fig. 58. Continued.

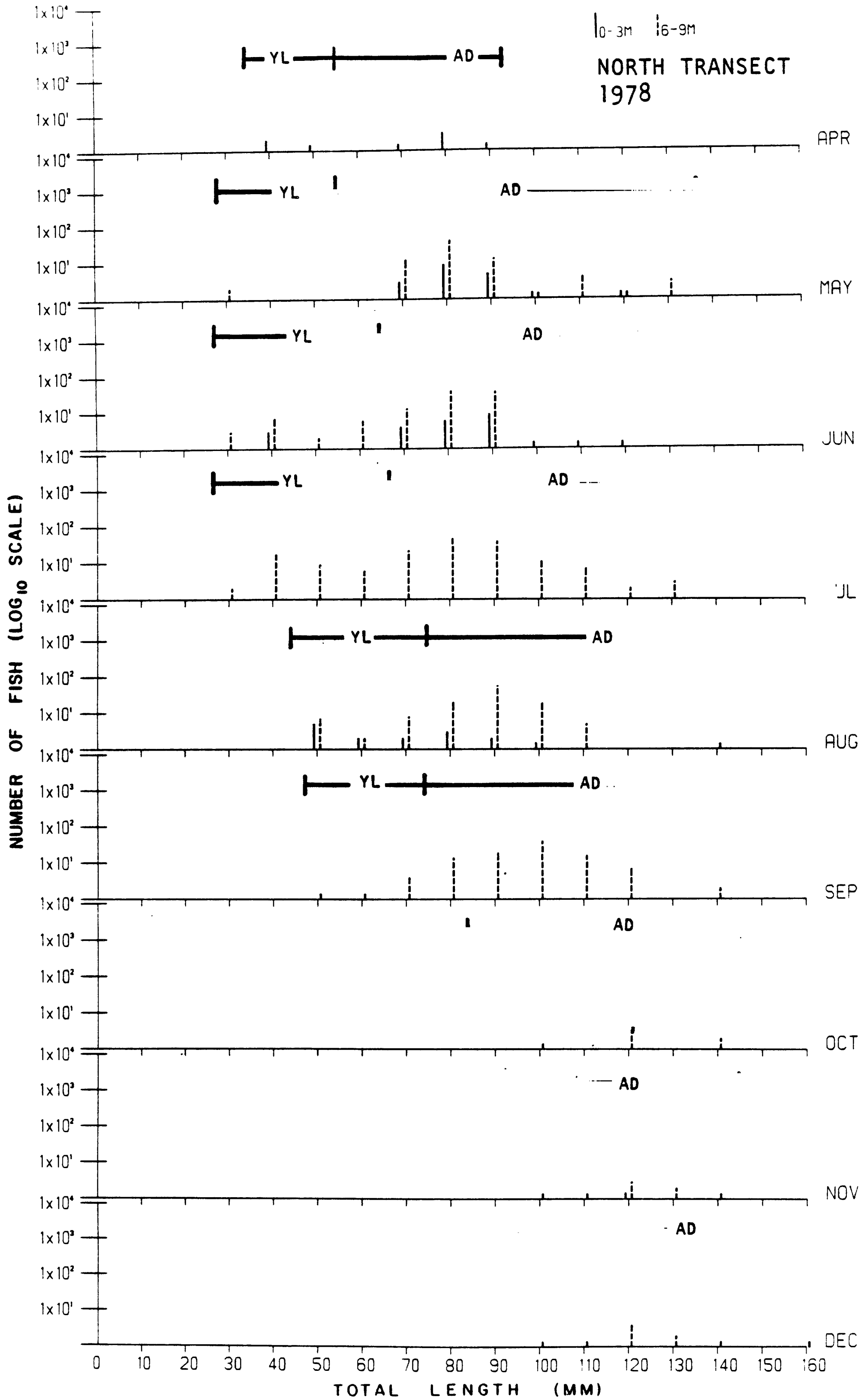


Fig. 58. Continued.

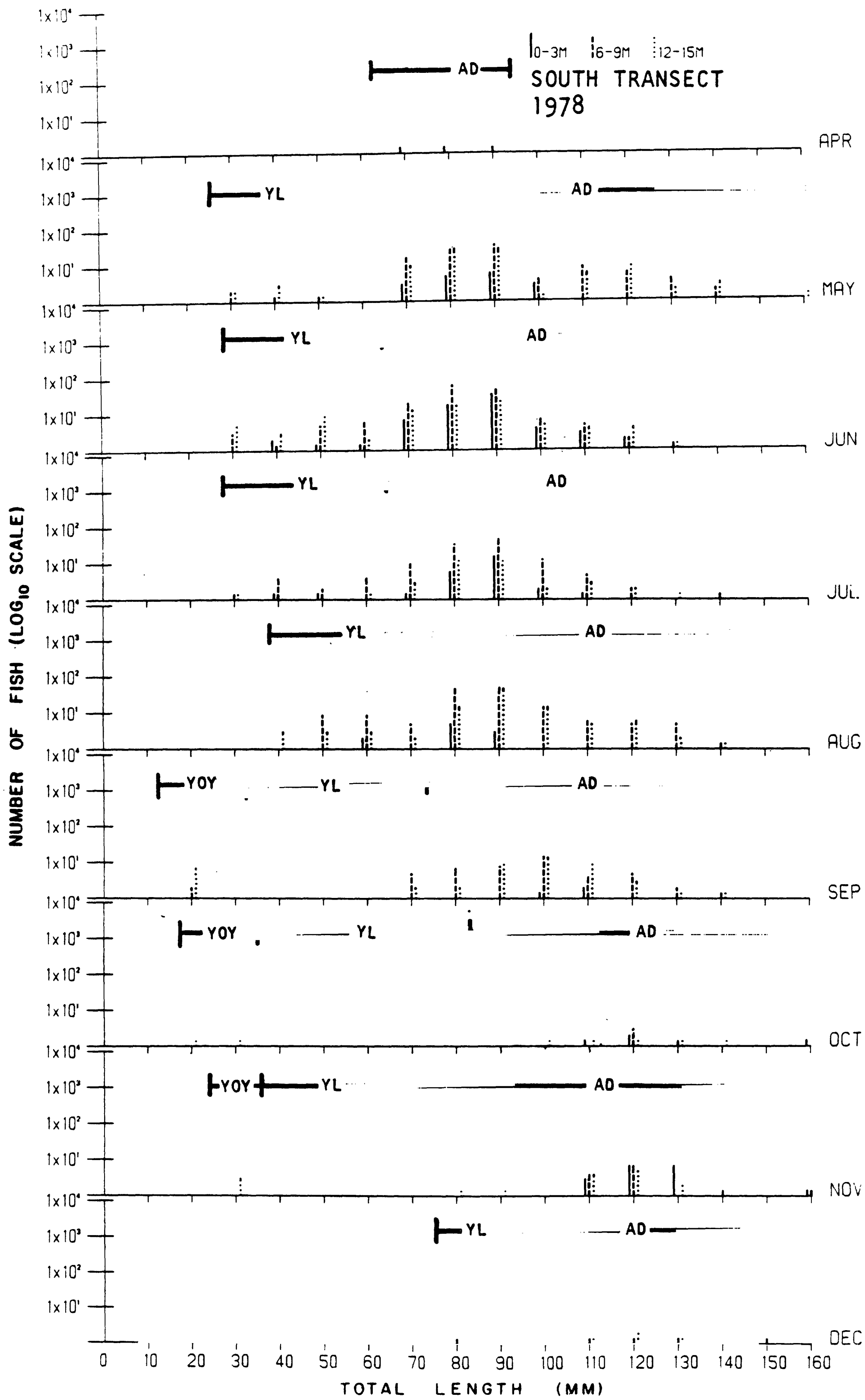
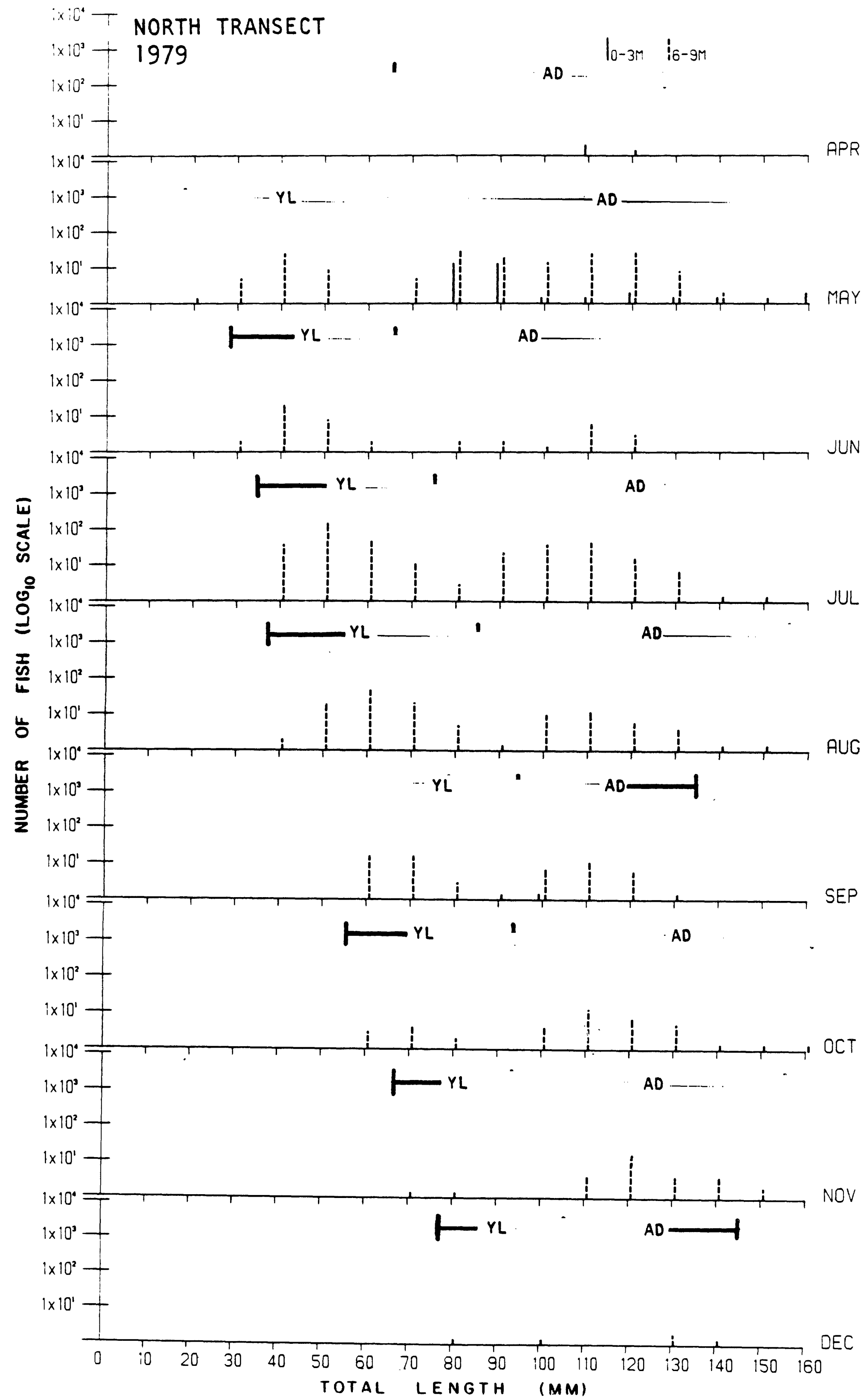


Fig. 58. Continued.



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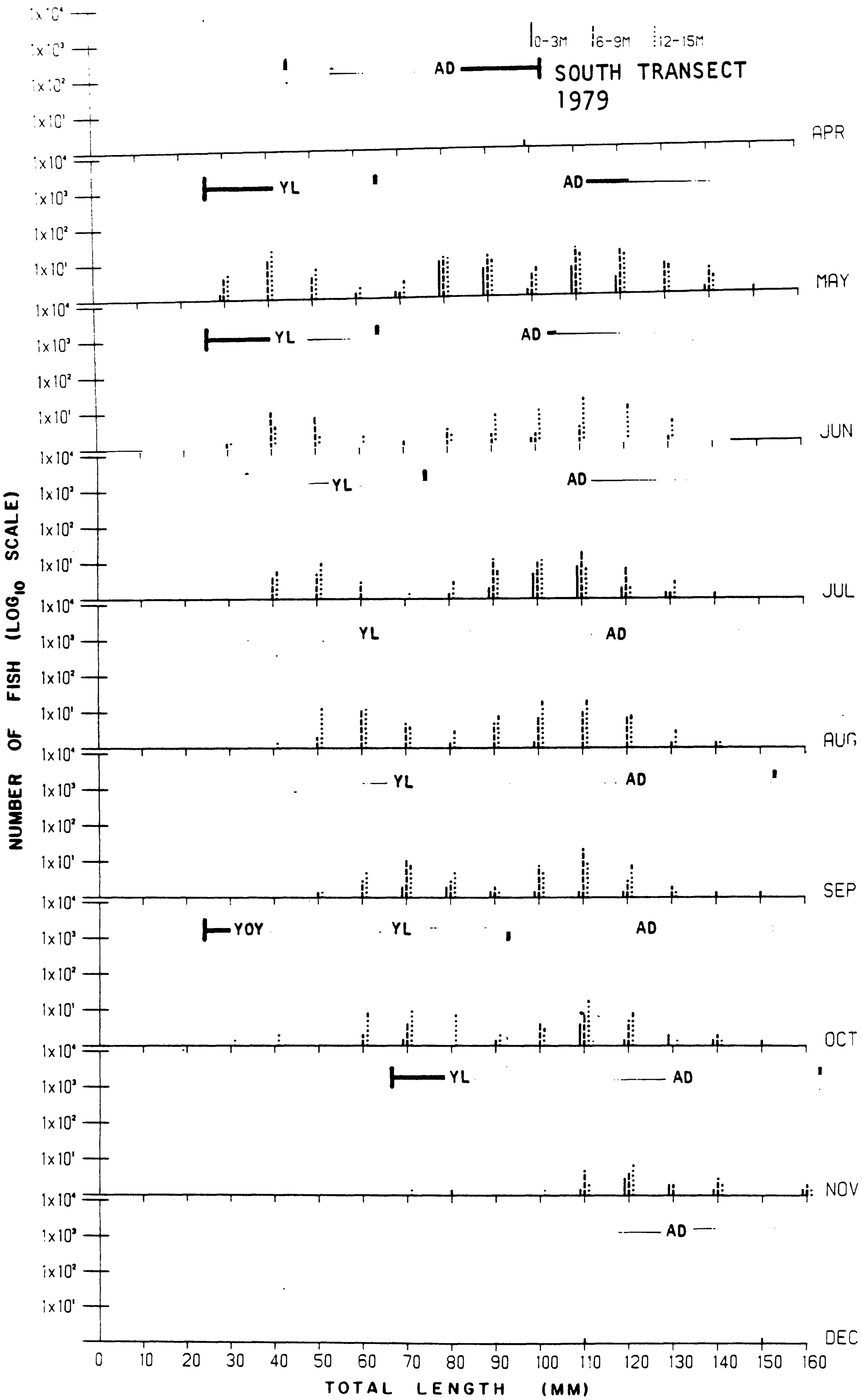


Fig. 58. Continued.

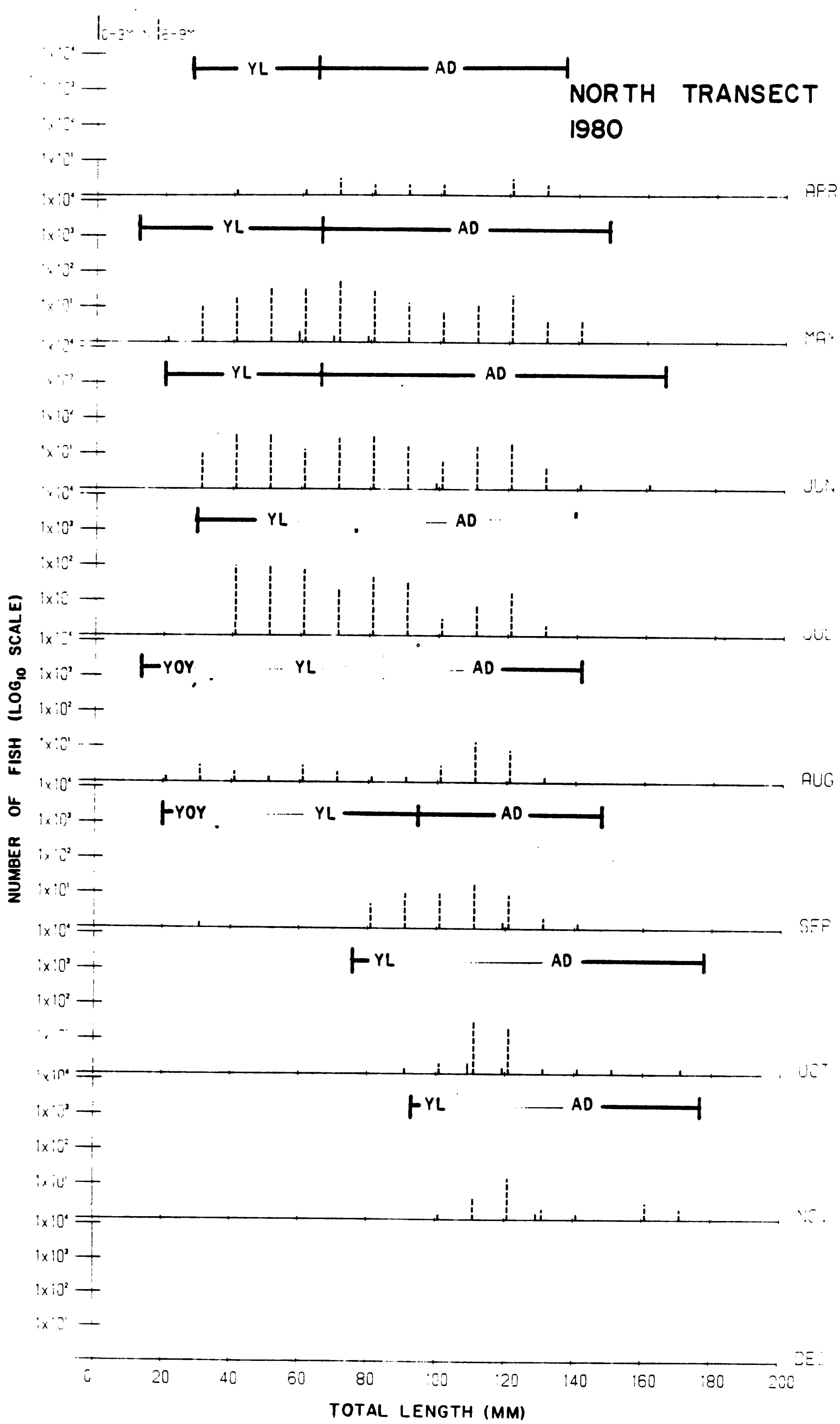


Fig. 58. Continued.

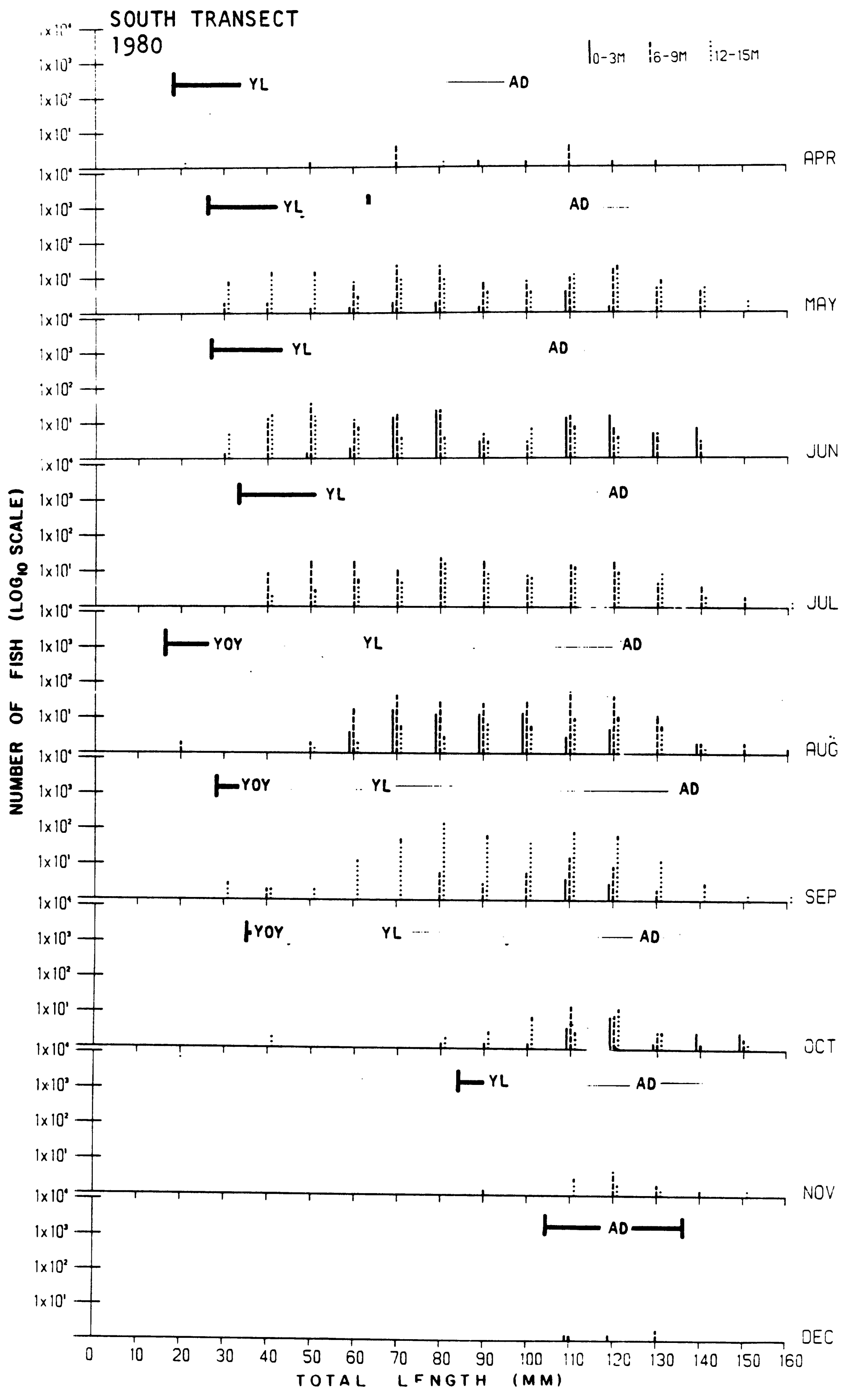


Fig. 58. Continued.

May--Catch of yearlings was fairly high during 1979 and 1980 (with 99 and 148 fish caught, respectively), but low throughout 1978. The 1977 year class was apparently relatively weak. Yearlings ranged in size from 25 to 54 mm (modal-length interval of 30 mm) in 1978, 15 to 54 mm (modal-length interval of 40 mm) in 1979 and 15 to 64 mm (modal-length interval of 50 mm) in 1980. Almost all yearlings were trawled; only a few were seined during the 4 yr study. Gill net meshes are too large to catch yearlings, as none were taken in this gear from 1977 through 1980.

In 1978-1979 yearlings were caught mainly at 9 m or deeper (Fig. 58); in 1979 some were caught at station L (6 m, north). They were caught during the day from 6 to 15 m and at night from 3 to 15 m. In 1980 yearlings were again most common at 9 m and deeper and at station L (6 m, north); during the day trout-perch yearlings were caught from 12 to 15 m and at night from the beach to 15 m. About half the yearlings (76 individuals) in May 1980 were caught at station N (9 m, north).

Substantial populations of yearlings during the 4 yr 1977 through 1980 were just entering the inshore area during May. Yearlings seem to accompany adults inshore during the spring and summer. Some trout-perch yearlings are sexually mature so their movement in the study area could be associated to a limited extent with spawning.

During May, as throughout the study period 1977 through 1980, trout-perch exhibited a pronounced diel migration characterized by a movement to shallow areas at night and a return to deep water during the day. Night catches were consistently higher than day catches. This migration was consistent for both adults and yearlings throughout the period of study; there were few exceptions to this pattern. Indeed, the difference between day and night catches was more pronounced for trout-perch than for any other major species, and the ANOVA test (see RESULTS AND DISCUSSION, Trout-Perch, Plant Effects) for diel period differences in trawl catches for trout-perch showed this time-of-day factor to be the most significant of all the factors tested for all major species. Net avoidance may also be partially responsible for low day catches.

Few trout-perch were caught in seine hauls throughout 1977-1980. Trout-perch did not prefer the beach zone, but seemed to prefer 6- to 12-m water. Trout-perch (yearlings and adults) feed chiefly on benthos, particularly chironomid larvae and amphipods (Jude et al. 1979b). Mozley (1975) found that chironomid larvae and amphipods were sparse in the 0- to 3-m zone compared with populations of these organisms farther offshore. Perhaps trout-perch were most common between 6 and 12 m when occupying the inshore area during spring and summer in response to location of food. Competition for food from spottail shiners and yellow perch in the beach zone may also limit trout-perch abundance there.

June--Catch of yearlings (25-64 mm, 50-mm modal-length interval) increased from 149 in May 1980 to 205 in June 1980. Catches in June for both 1978 and 1979 were lower than the respective May catches with 59 yearlings caught in June of each year; however, in 1977 yearling catch was near a peak in June at 152 fish. Yearlings ranged in size from 25 to 64 mm in June for

all 4 yr. The June modal-length interval was 50 mm for all 4 yr except in 1979 when it was 40 mm. Yearlings were generally caught from 9 to 15 m during the day and from the beach to 15 m at night, except for a total of 10 yearlings caught during the day in the beach zone in 1978 and 1980.

In June yearlings were most common between 6 and 12 m. Again, high night catches and very low day catches indicated a migration of trout-perch into the study area at night and back to deeper water during the day. Net avoidance probably also contributed to low day catches.

July--July marked an influx of yearlings into the study area during 1977, 1979 and 1980. Catch of yearlings peaked in July 1980 at 351 individuals, at 275 fish in July 1979 and at 192 fish in July 1977; the 1978 yearling catch (25-64 mm, 40-mm modal-length interval) was relatively low throughout the year. In both 1979 and 1980 lengths ranged from 35 to 74 mm with a 50-mm modal-length interval, while in 1977 yearlings (45-74 mm, 60-mm modal-length interval) were slightly larger than in 1979 or 1980. Yearlings were caught from 6 to 15 m during the day and night with most trawled between 6 and 12 m (Fig. 58). High catches of yearlings occurred at station N (9 m, north) in 1979 and at station L (6 m, north) in 1980. Reasons for these relatively high catches of yearlings are not clear. The high catch in 1979 occurred during an upwelling, while in 1980 the catch was taken at a fairly high water temperature (21.0 C). Yearlings may have been attracted to the north transect to feed on organisms stirred into the water column by construction activity.

August--Catch of yearlings declined considerably from July to August with 148 individuals caught in 1980, 146 in 1979 and 58 in 1977. In 1978 catch of yearlings (35-74 mm TL, 50-mm modal-length interval) increased slightly from 49 individuals in July to 62 individuals in August. During August yearlings ranged in length from 35 to 84 mm in 1979 (60-mm modal-length interval), and the modal-length interval was 70 mm in 1977 and 1980. Yearlings in 1980 grew substantially from July to August with the modal-length interval increasing from 50 mm to 70 mm; this was the highest growth of yearlings shown for any 2 consecutive mo during the 4-yr study. In 1980 no upwellings were observed between July and August, while upwellings occurred in July during 1977 through 1979. A major upwelling occurred in July 1979, followed by somewhat lower than average water temperatures for August 1979; this may explain the lower growth shown by yearlings during 1979.

Yearlings in August were caught from 6 to 15 m during the day and from the beach to 15 m at night. In August as for most months during 1979, most trout-perch (both yearlings and adults) were caught at 9- to 12-m stations on the south transect and at 6 to 9 m on the north transect. For the other 3 yr (1977, 1978 and 1980) most trout-perch were caught at stations mentioned above plus the 6-m station on the south transect. Yearlings migrated toward shore at night and toward deeper water during the day; the only exception to this pattern was a relatively high day catch of yearlings at station N (9 m, north) in 1979.

In August 1980 substantially more trout-perch (yearlings and adults) were caught at the south transect 6- to 9-m stations than at the complement of those stations at the north transect (Fig. 58). Reasons for this difference are not clear. During most of 1979 (including August) catch at north transect stations was substantially higher than at south stations (see RESULTS AND DISCUSSION, Trout-Perch, Plant Effects).

September--Catches of yearlings (45-94 mm, 70-mm modal-length interval) continued to decline through September 1979 when 81 individuals were caught (Fig. 58). However, catch increased from August to September both in 1977 and 1980. Of the 309 yearlings (45-94 mm, 80-mm modal-length interval) caught in September 1980 most were trawled at 12- and 15-m stations on the south transect, particularly at 15 m. During September 1977 most of the 101 trout-perch yearlings caught were captured at the south transect at depths of 9 and 12 m (Fig. 58). High catches in deeper water in 1980 indicate that offshore migration of trout-perch yearlings may possibly have begun by sampling time in September. Abundance of yearlings and adults in the Cook Plant study area declined in September in southeastern Lake Michigan (Jude et al. 1975). The 1979 catch data for the Campbell Plant area indicated a movement toward offshore beginning in August and continuing through September. Apparently in 1977 offshore migration of yearlings started in late September or October. In September 1978, the yearling (45-74 mm) migration probably began in September. In 1978 and 1979 most yearlings were caught between 6 and 12 m (note that in 1977 two yearlings were trawled in water between 18 and 21 m at the south transect).

Yearlings grew substantially through September. House and Wells (1973) found mean lengths of yearlings were 49 mm in June and 83 mm by the end of their second year of life in southeastern Lake Michigan. For our study area in both 1977 and 1980 yearlings reached a mode of 50 mm in June and 80 mm in September. In 1979 yearlings reached a modal-length interval of 40 mm in June and 70 mm in September. In July 1979 and 1980 the modal-length interval was 50 mm. Growth apparently was slightly lower in 1979 than 1980 due to lower water temperatures in July and August 1979.

October, November and December--Most yearlings had left the study area by October. Catch declined drastically from September to October during 1977 and 1980 when only eight yearlings (65-94 mm) were caught in October during each of those years. In 1979 catch of yearlings (55-94 mm) also declined in October with 43 individuals caught, while in 1978 no yearlings were caught in October. It appeared that migration to the offshore area was more gradual in 1979 than in other years. Yearlings were chiefly caught from 9 to 15 m during the day and 6 to 15 m at night. One yearling in 1979 was caught in a seine haul at beach station P (south reference) and six were trawled at station H (21 m, south) in 1977.

Only a few yearlings were caught in November and December indicating that almost all yearlings had left the study area by November. Only 13 yearlings were caught during these 2 mo over the 4-yr study period. All were collected in 6 m or deeper water.

Adults--

Adults (2-yr or older) comprised about 64% of the total adult and juvenile catch for the years 1977 through 1980 pooled. Annual adult catch was in general greater than that for yearlings. Adults include several age-groups while yearlings include just one; this partially explains the difference in catch between yearlings and adults. Furthermore adults are in the inshore waters (and thus susceptible to our sampling effort) by May; whereas, the yearling population does not show peak occurrence inshore until July. Also a small population of adults tends to stay in the inshore waters through fall, while almost all yearlings have migrated from the study area by October.

The annual total adult catch was highest in 1978 and 1980 with 1626 and 1694 trout-perch caught, respectively. Adult catch was lower in 1979 (1043 fish) and substantially lower in 1977 (366 fish). The annual yearling catch was highest in 1980 (1175) and lowest in 1978 (only 201 fish). Yearling fish catch in 1977 was 513 fish, and 709 yearlings were caught in 1979. Total adult and juvenile catch was highest in 1980 (2885 fish); the 1980 total catch was considerably greater than that for 1978 (1841 fish), 1979 (1755) or 1977 (893 fish). However, this increase in 1980 total catch does not imply a trend of increasing trout-perch populations in the Campbell Plant vicinity of Lake Michigan but rather a high catch year in a series of fluctuating catches. Note that adult catches for 1978 and 1980 were about equal.

<u>Seasonal distribution</u>--

April--April marks some adult trout-perch spring migration inshore in Lake Michigan. Catch data indicate only a few trout-perch migrated into the study area by sampling time in April for 1978 through 1980 (Fig. 58). Eight adults (65-114 mm) were caught in 1978 and four adults (95-124 mm) were caught in 1979; seven of these adults were seined, two were trawled and one was caught in a bottom gill net. In 1980, 2 adults were caught in bottom gill nets between 6 and 9 m and 25 were trawled between 3 and 12 m.

All adults collected in April had well developed gonads, except for two in 1978. These two, a ripe-running male and a ripe-running female, indicated trout-perch began spawning that year in April. In April 1979 a trout-perch larva (6.5 mm TL) was collected in a larvae tow sample indicating that spawning also began in April during 1979.

May--Migration of adult trout-perch inshore increased dramatically from April to May. Indeed catch of adults was at its peak in 1979 and 1980 (catch of 341 and 322, respectively) and near its peak in 1978 (308 adults). Adults (65-164 mm) were caught from the beach zone to 15 m with most trawled from 6 to 12 m (Fig. 58).

Spawning activity increased during May from April levels as more fish with well developed and ripe-running gonads were caught; this was consistent for 1978 through 1980 (Fig. 59). Spent individuals were also collected in May from 1978 through 1980.

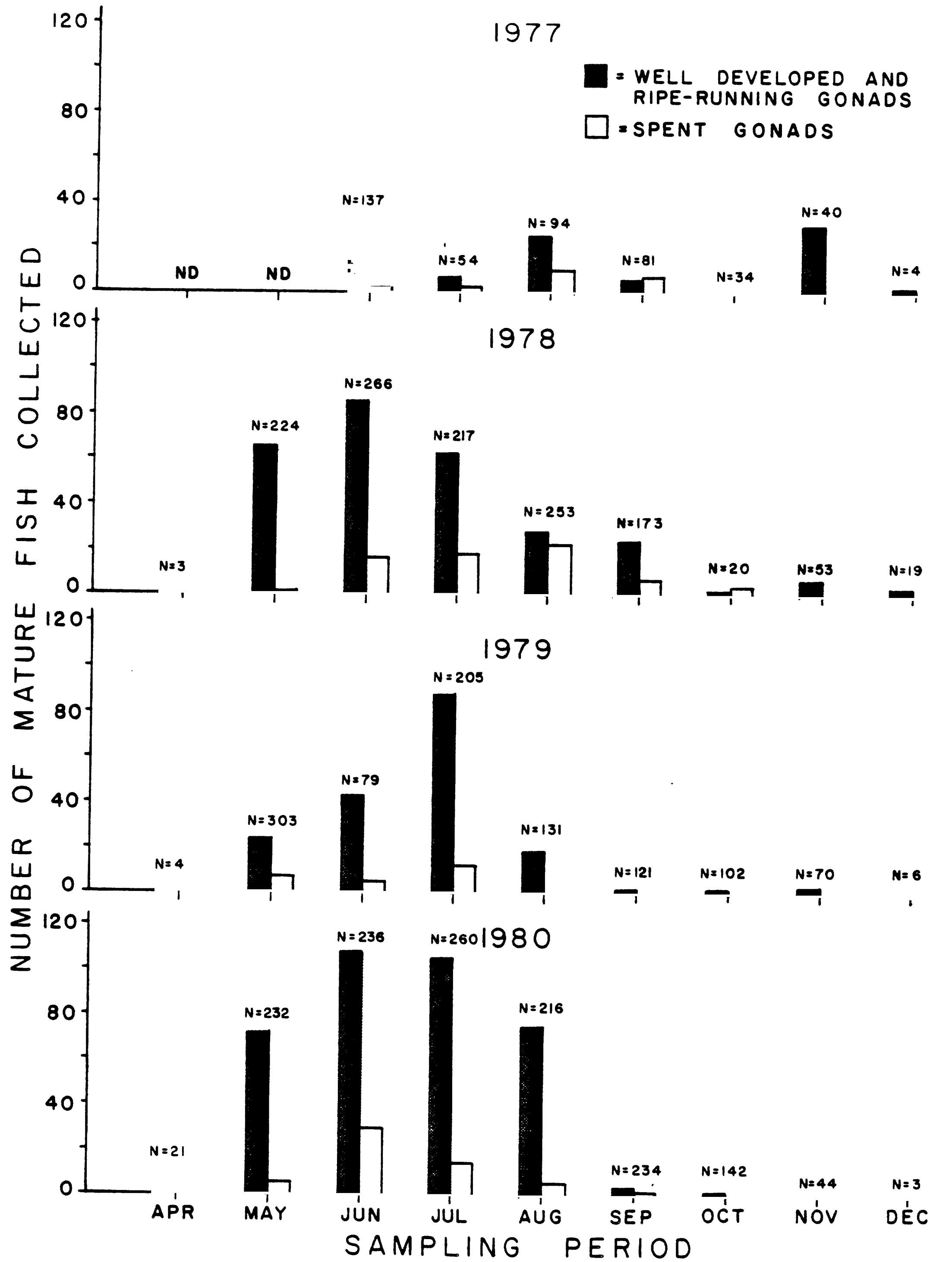


Fig. 59. Number of mature trout-perch with well developed, ripe-running and spent gonads collected monthly during June-December 1977 and April-December 1978-1980 near the J. H. Campbell Plant, eastern Lake Michigan. N = total number of mature trout-perch caught per month.

Length of age-2 fish ranged from approximately 65 to 104 mm and age-3 fish ranged from 95 to 124 mm each May during 1978 through 1980. Age-2 fish were separated from age-3 fish based on length-frequency data and by comparison with data from the study by House and Wells (1973), who aged fish by reading scales.

Numbers of adults caught in May during 1977 through 1980 were similar; however, the percentage that age-2 adults comprised of the total number of adults caught, varied considerably among years. In 1978 over 80% of the adults were 2-yr-old fish. These fish were members of the strong 1976 year class noted by Jude et al. (1978, 1979a). This year class was apparently the strongest year class observed during the 4-yr study. The 1979 adult catch consisted largely (about 50%) of 3-yr-old fish which again were representatives of the strong 1976 year class. Evidently the 1976 year class survived the 1978-1979 winter well and was present in relatively high numbers. The number of age-2 fish collected in 1979 was not as high as in 1978; these 1979 age-2 fish represented the relatively less abundant 1977 year class. Whereas the yearling age-group was relatively small in 1978, there was a high catch of yearlings in 1979 suggesting a relatively more successful 1978 year class compared with 1977. Most trout-perch mature at age 2 (House and Wells 1973) so the 1976 year class was probably the major parent stock for this 1978 year class. In May 1980 age-2 adults represented over 55% of the total adult catch. As in 1979, age-3 adults were well represented in 1980 suggesting high survival of age-2 fish over the 1979-1980 winter. Although there seemed to be some correlation between parent stock and year-class strength, Magnuson and Smith (1963) found environmental conditions, such as water temperature and wind velocity, more important than size of the parent stock in determining year-class strength of trout-perch in Red Lakes, Minnesota.

June--High adult catches were recorded in June during 1977 (174 adults), 1978 (393 fish) and 1980 (315 fish). Both yearling and adult catch declined from May to June during 1979 with only 78 adults caught in June 1979. Reasons for this decline are not known. There was no upwelling at sampling time which could have affected trout-perch distribution. Bottom temperatures for trawling ranged from 14 to 17 C.

Adults (65 mm or greater) were caught from 3 to 15 m during the day and from the beach to 15 m at night (Fig. 58). Most adults were trawled, but 30 were seined in June and 22 were caught in bottom gill nets during 1977 to 1980. Most trout-perch were caught at night in bottom gill nets, when migrating inshore.

In June trout-perch (adults and yearlings) were most common between 6 and 12 m; however, in 1980 a substantial adult catch was taken from station B (3 m, south). Similar to the pattern exhibited by yearlings, high night catches and very low day catches illustrated a migration of trout-perch into the study area at night and into deeper water during the day. Again, there may be some net avoidance during the day. Three adults were trawled at stations 18 to 21 m at the south transect in June 1977.

June was the peak spawning month each year from 1977 to 1980, which coincides with peak catch or near peak catch (in the case of 1980) for all years except 1979 (Fig. 59). During all years except 1979 more trout-perch with well developed or ripe-running gonads were caught in June than any other month of the sampling year. For 1979 gonad data suggest a spawning peak in June despite the unusually low number of adults caught (Jude et al. 1980). The spawning peak in 1979 may have occurred just before our sampling period in June with most adults leaving the vicinity immediately after spawning.

Adults can suffer high mortality after spawning (Scott and Crossman 1973); however, age-3 fish were well represented in 1980 so this die-off probably did not occur in 1979. Scarcity of individuals 3-yr old or older (100-160 mm) in May in the 1977 and 1978 collections tended to corroborate high mortality of adult trout-perch (age 2 or older) in 1976 and 1977. We have not observed die-offs of trout-perch nor have die-offs been observed in southeastern Lake Michigan (Jude et al. 1975).

July--Adult trout-perch catch was high in 1978 (308 fish), in 1979 (239 fish) and 1980 (275 fish). Adult catch was low in July 1977 (29 fish) as it was throughout 1977. Adults were caught from 6 to 15 m during the day and from 3 to 15 m at night (except for three adults in the beach zone in 1978). Few trout-perch were caught in bottom gill nets in July.

Most trout-perch were trawled at stations 6 to 15 m at the south transect and 6 to 9 m at the north transect (Fig. 58). In July 1979 adult catch at station C (6 m, south) was relatively low. Again catch data indicate a migration of adults and yearlings shoreward at night and into deeper water during the day. However, there were relatively high adult day catches at station N (9 m, north) in 1979 and at station L (6 m, south) in 1980.

Spawning activity appeared to be high through July, but had declined somewhat from June levels (Fig. 59). For 1979, data showed a secondary spawning peak in July. In June 1979 a higher percentage of mature (well developed, ripe-running or spent gonads) fish were collected than in July 1979; however, the number of mature fish collected was greatest in July during 1979. Peak spawning occurred in July in the Cook Plant vicinity during 1973 and 1974 (Jude et al. 1979b).

August--Catch of adults was high in August 1978 (338 fish) and 1980 (275 fish). Catch in 1977 was low (71 fish). In 1979 adult catch declined substantially between July and August; apparently migration offshore had begun as early as August. A major upwelling in July followed by comparatively cool water temperatures in August (Fig. 22) may have triggered this earlier migration offshore. Adults were collected from the beach to 15 m at night (with two adults caught between 18 and 21 m in 1977) and from 9 to 15 m during the day. Again most were caught from 6 to 12 m at the south transect and 6 to 9 m at the north transect. In August 1980 there was a considerable catch of trout-perch from station B (3 m, south) (Fig. 58). Also during August 1980 there was a substantially greater catch of trout-perch at the south transect than the north. Reasons for this difference are unclear.

Spawning activity declined from July to August during 1978 through 1980 (Fig. 59). During 1977 a secondary spawning peak occurred in August with a few ripe-running individuals caught. Gonad data were not strong indicators of continued spawning in August 1978, 1979 and 1980. However, newly hatched larvae collected during August and September suggest spawning continued through late August and probably early September.

Again adults migrated shoreward at night and towards deeper water during the day; however, there were a few relatively large day catches of adults. These included day trawls at 9 and 12 m at the south transect during 1980.

September--Adult catches declined from August to September during 1977 through 1979. Migration offshore had begun by sampling time in September. In 1979 migration of adults offshore was well underway in September, probably having begun in August. This movement offshore appeared to have just started by September during 1980. Although adult catch increased slightly from August to September in 1980 (293 adults caught), most fish (over 50%) were caught at station F (15 m, south) and about 35% were taken at station E (12 m, south). These high catches from deeper water signalled the start of the adult migration offshore. Generally, in September adults were found from 6 to 15 m during the day and from the beach to 15 m at night during all years 1977 through 1980 (Fig. 58).

October, November and December--Apparently a small population of adult trout-perch remained in the study area during fall months (Fig. 58). Monthly catches of adult trout-perch ranged from 20 to 139 fish during the 4-yr study for October and from 40 to 68 fish for November. Adults were caught only at 15 m during the day and from the beach to 15 m at night. Their movement inshore at night and offshore during the day was still evident in October and November. In 1980 bottom gill net catch peaked in October with 67 adults caught. In 1977, 1978 and 1979 bottom gill net catch peaked in November with 21, 24 and 39 adults caught, respectively. All trout-perch caught in bottom gill nets were adults. Five adults were caught in a surface gill net at station C (6 m, south) at night in November 1979 (one adult was caught by this gear in May 1978). The trout-perch is considered a benthic species; however, some move upward in the water column. By December most adults remaining inshore through fall had left the study area.

Other Considerations--

Trout-perch were not found to be an important forage species in various areas of southeastern Lake Michigan (Jude et al. 1979b; House and Wells 1973). During our study from 1977 to 1980, trout-perch were seldom found in stomachs of predatory fishes. Trout-perch may act as a nutrient transporter in the study area since they move into shallow water at night and back into deeper water by day (Scott and Crossman 1973).

Temperature-catch Relationships--

Trout-perch appeared to tolerate a wide range of water temperatures. During 1977 through 1980 most trout-perch were caught at water temperatures between 4 and 22 C in the study area.

Response of trout-perch to changes in water temperature varied considerably. In 1977 trout-perch catches increased with increasing water temperatures. In July 1978 an upwelling may have caused a decline in the number of adults collected compared with June 1978. However, in 1979 increasing water temperatures from May to June did not lead to an increase in trout-perch catch. Also, when an upwelling occurred in July, more trout-perch were collected than in June; water temperatures at times of trawling were considerably lower in July than in June. SCUBA divers observed that trout-perch seemed unaffected by an internal seiche in Georgian Bay, Lake Huron, and that the fish continued to feed while moving slowly just above the bottom (Emery 1970). These SCUBA observations further support the lack of temperature preference of trout-perch. In southeastern Lake Michigan, trout-perch tended to move to warm-water areas at times, but remained indifferent or were attracted to cool water at other times (Jude et al. 1979b). In 1977 yearling trout-perch tended to occur in cooler water than adults in the Campbell Plant study area; however, from 1978 through 1980 no pattern of temperature preference was apparent in catch data.

Plant Effects--

To help evaluate Campbell Plant effects on trout-perch, ANOVAs were performed on trawl data for adult and juvenile trout-perch caught in Lake Michigan from 1977 to 1980. An ANOVA for just 1977 data, for only the 6-m stations at the north and south transects (stations L and C, respectively) showed no significant difference in catches between these two stations (Jude et al. 1978). The ANOVA for 1977 through 1980 trawl data for stations C and L showed average catch at station L (6 m, north) was significantly greater than that for 6 m south transect station C (Table 37). Another ANOVA was performed on trout-perch adult and juvenile catch data for both the 6- and 9-m stations at both transects for 1978 to 1980. Results showed that AREA was a significant main effect and that the YEAR x AREA interaction was significant (Table 38). Apparently the considerably greater catch at the plant vicinity than at the reference area in 1979 contributed to the significant AREA effect and the significant YEAR x AREA interaction (Fig. 60). Catch in the plant vicinity was significantly greater than at the reference area, mainly due to the 1979 catch difference.

During 1979 there was much construction activity in the discharge area (plant vicinity) and most of the riprap was also being deposited. This activity may have stirred organisms from the lake bottom making them more available to yearling and adult trout-perch to feed upon, thus attracting trout-perch to the plant transect area. With construction activity completed there probably will be no substantial difference in adult and juvenile catch between areas in 1981, unless the riprap remains attractive to trout-perch.

Table 37. Analysis of variance summary for trout-perch caught in trawls at stations C (6 m, south) and L (6 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1977 through 1980. Data for June through November were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	3	0.2522	8.3536	0.0001**
Month	5	2.4533	81.2655	<0.0001**
Station	1	0.3915	12.9682	0.0005**
Time	1	37.6511	1247.1904	<0.0001**
Y x M	15	0.4432	14.6813	<0.0001**
Y x S	3	0.1520	5.0361	0.0028*
M x S	5	0.2020	6.6896	<0.0001**
Y x T	3	0.2970	9.8379	<0.0001**
M x T	5	0.9659	31.9946	<0.0001**
S x T	1	0.0011	0.0349	0.8522
Y x M x S	15	0.1306	4.3275	<0.0001**
Y x M x T	15	0.3139	10.3964	<0.0001**
Y x S x T	3	0.1404	4.6507	0.0044*
M x S x T	5	0.0491	1.6254	0.1606
Y x M x S x T	15	0.0494	1.6365	0.0782
Within cell error	96	0.0302		

** Highly significant ($P < 0.001$).
* Significant ($P < 0.01$).

Trout-perch larvae data suggest that trout-perch may be attracted to the riprap vicinity to spawn (see RESULTS AND DISCUSSION, Trout-Perch, Larvae). Most larvae collected were caught in 1980 (28 larvae); many (23 larvae) were caught at the north (plant) transect. The numbers of larvae caught were too low to draw a conclusion. If trout-perch tend to spawn near or on the riprap, operation of the offshore intake will increase the 1981 entrainment loss for trout-perch over levels observed for Units 1 and 2 during 1978 through 1980. Losses due to entrainment were relatively low during 1978 and 1979.

Unidentified Coregoninae

Introduction--

Throughout the 4-yr study of fish abundance and distribution in southeastern Lake Michigan the population of fishes in the subfamily Coregoninae has shown a dramatic increase. Although unidentified Coregoninae has always been between the fourth- and sixth-most abundant species/group in our catches, the overall catch has increased from 460 fish in 1977 to 8934 in 1980. The increase in abundance has been accompanied by a change in the length-frequency distribution of fishes collected. In 1977 unidentified Coregoninae ranged from about 35 to 294 mm. Three groups were apparent, those in the 70- and 80-mm length intervals, those in the 100 to 150-mm length

Table 38. Analysis of variance summary for trout-perch caught in trawls at stations C (6 m, south), D (9 m, south), L (6 m, north) and N (9 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1978 through 1980. Data for May through November were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	2	0.4669	11.3316	<0.0001**
Month	6	4.3418	105.3659	<0.0001**
Area	1	0.5383	13.0634	0.0004**
Depth	1	1.4526	35.2512	<0.0001**
Time	1	57.3189	1390.9978	<0.0001**
Y x M	12	0.3387	8.2191	<0.0001**
Y x A	2	0.5675	13.7713	<0.0001**
M x A	6	0.2125	5.1579	0.0001**
Y x D	2	0.3498	8.4889	0.0003**
M x D	6	0.1619	3.9289	0.0011*
A x D	1	0.2147	5.2111	0.0237
Y x T	2	0.3600	8.7357	0.0002**
M x T	6	1.0786	26.1754	<0.0001**
A x T	1	0.0217	0.5258	0.4694
D x T	1	1.2634	30.6588	<0.0001**
Y x M x A	12	0.2657	6.4469	<0.0001**
Y x M x D	12	0.4589	11.1365	<0.0001**
Y x A x D	2	0.1327	3.2211	0.0424
M x A x D	6	0.0565	1.3709	0.2291
Y x M x T	12	0.4022	9.7608	<0.0001**
Y x A x T	2	0.0024	0.0574	0.9442
M x A x T	6	0.1125	2.7289	0.0148
Y x D x T	2	0.1769	4.2940	0.0152
M x D x T	6	0.3784	9.1821	<0.0001**
A x D x T	1	0.1418	3.4404	0.0654
Y x M x A x D	12	0.2416	5.8626	<0.0001**
Y x M x A x T	12	0.1009	2.4480	0.0058*
Y x M x D x T	12	0.1459	3.5419	0.0001**
Y x A x D x T	2	0.2101	5.0975	0.0071*
M x A x D x T	6	0.1386	3.3645	0.0037*
Y x M x A x D x T	12	0.0851	2.0641	0.0218
Within cell error	168	0.0412		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

intervals and those in the 200- to 250-mm length intervals (Fig. 61). In 1978 most unidentified Coregoninae were between 65 and 84 mm and almost no fish greater than 180 mm were collected (Fig. 61). During 1979 two groups of unidentified Coregoninae were collected, those in the 70- to 120-mm length intervals and those in the 160- to 180-mm length intervals. Very few fish greater than 240 mm were caught (Fig. 61). Finally in 1980 most fish collected were within the 60- to 80-mm length intervals, the 170- and 180-mm length intervals and, for the first time since 1977, a substantial number of

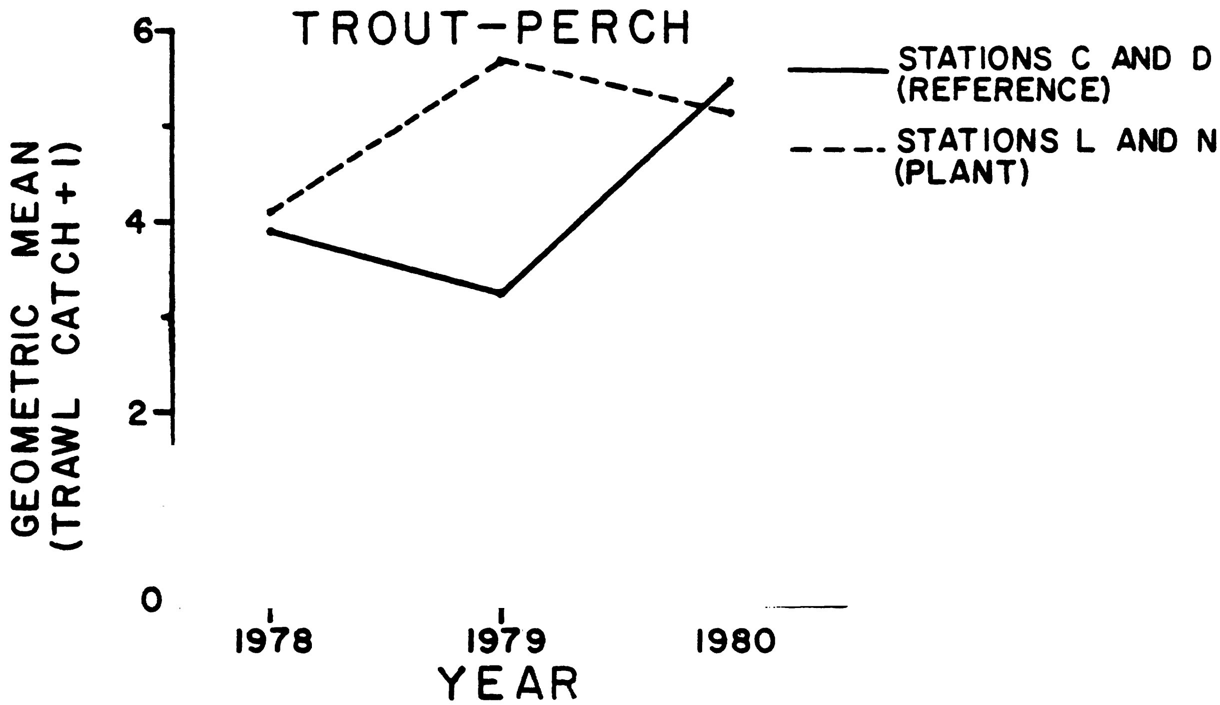


Fig. 60. Geometric mean number plus one of trout-perch caught in trawls at stations C (6 m, south), D (9 m, south), L (6 m, north) and N (9 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1978 through 1980. Graph illustrates the YEAR x AREA interaction.

fish in the 270- to 310-mm length intervals were collected (Fig. 61). The increase in abundance and the increased number of larger individuals collected over the 4-yr period are clearly shown in Figure 62.

Trawling was the most effective gear in collecting unidentified Coregoninae, however each gear used was size-selective and trawl hauls tended to collect YOY or yearling unidentified Coregoninae in the 30- to 280-mm length intervals (Tables 39 and 40). Gill nets retained fewer fish but those that were netted were usually larger, in the 90- to 310-mm length intervals. Seining collected numerous small unidentified Coregoninae between 45 and 124 mm (Table 40). Catches of unidentified Coregoninae were usually greater during the night than during the day for all gear types except the seine which had greater catches during the day. Surface gill net catches of Coregoninae were made only during the night (Table 39). Unidentified Coregoninae were caught at a wide range of water temperatures, 1 to 23 C. This was particularly true for those fish caught by trawl or bottom gill net. Seining and surface gill net sets captured fish only when water temperatures ranged from 9 to 19 C, even though these gear were deployed at temperatures between 3 and 25.7 C.

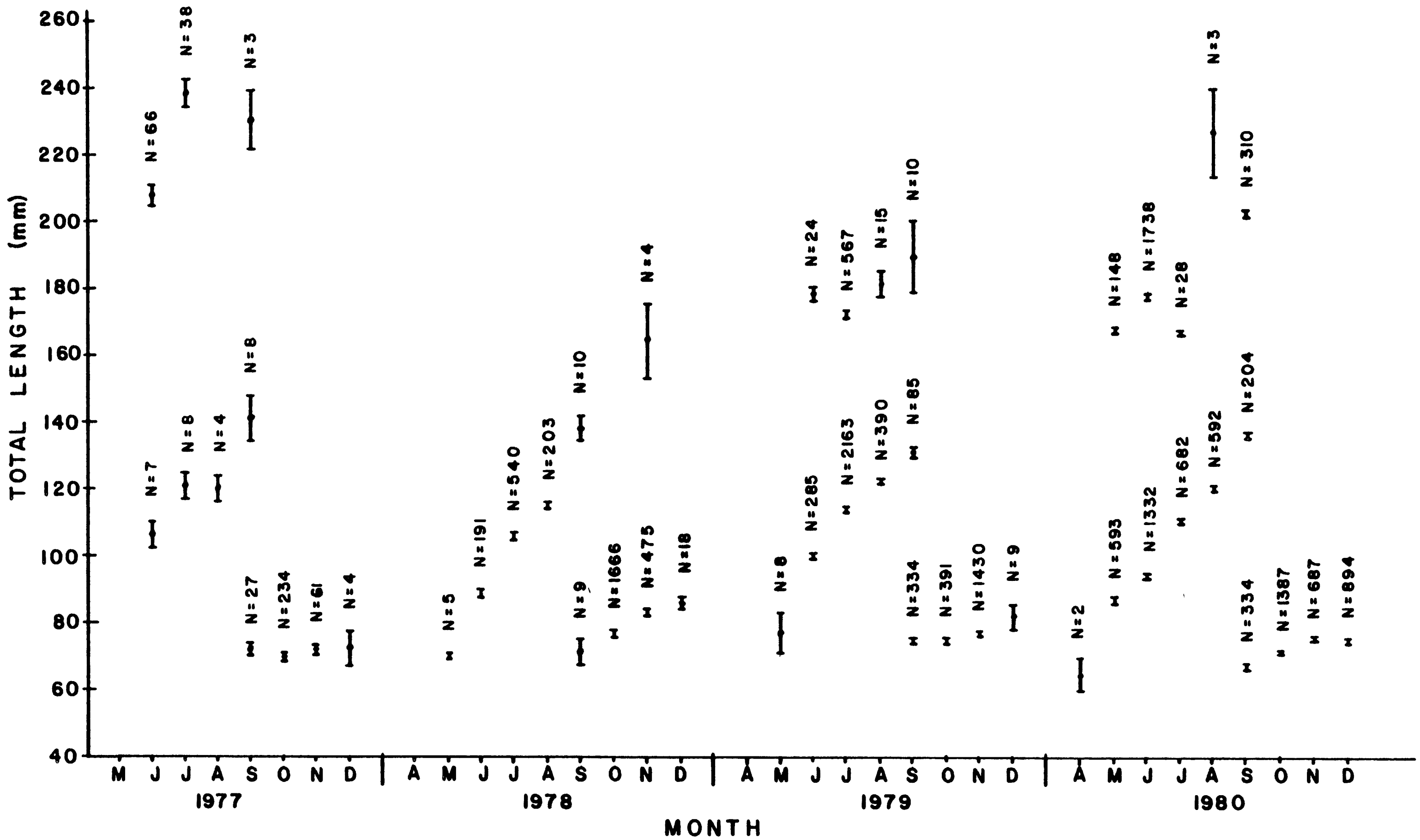


Fig. 61. Monthly average length of unidentified Coregoninae collected in all sampling gear in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1977 to 1980. Bar indicates standard error. N = number of observations.

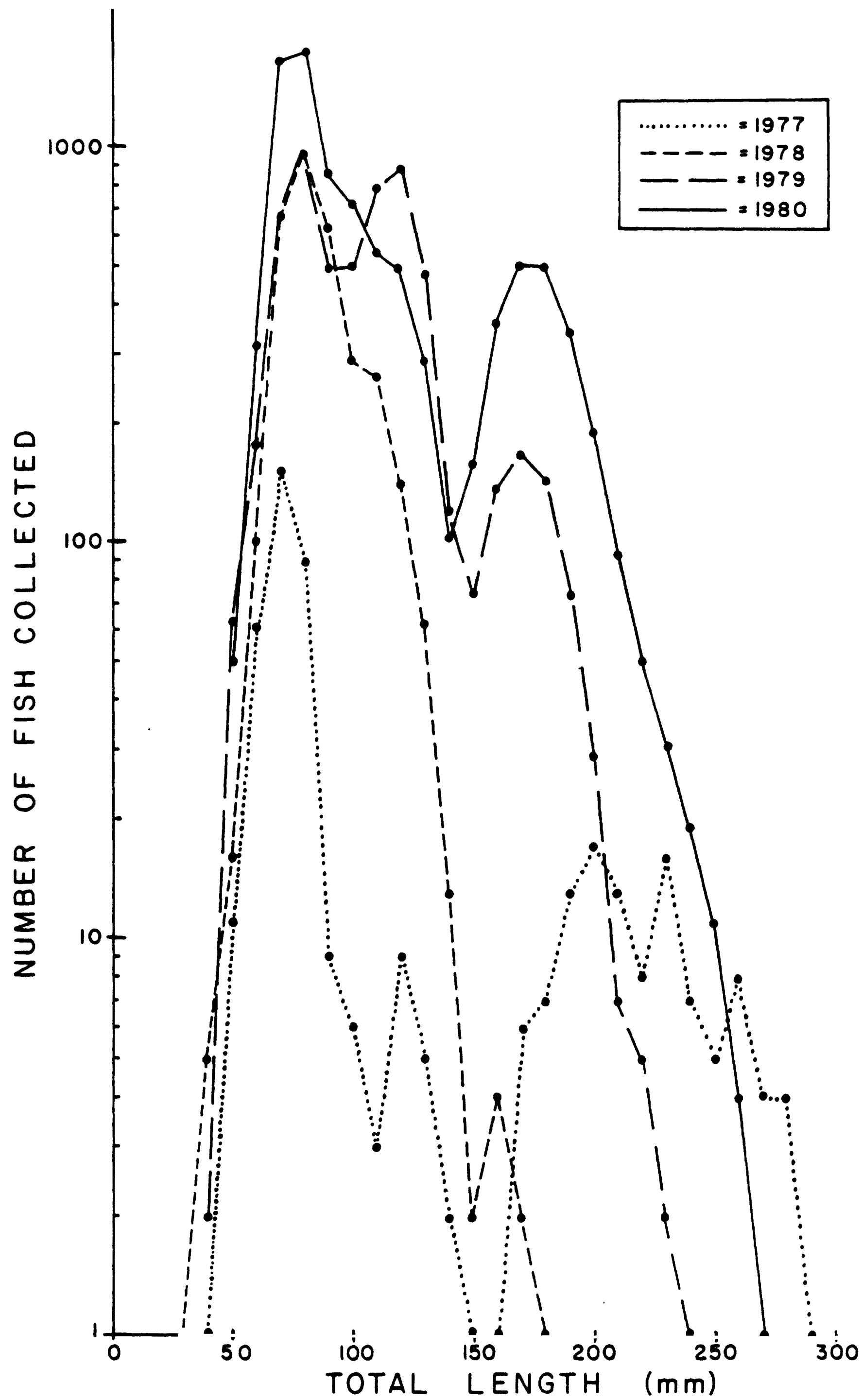


Fig. 62 . Total number of unidentified Coregoninae collected within each length-frequency interval (pooled over months) in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1977 to 1980.

Table 39. Total number of unidentified Coregoninae collected by each type of sampling gear in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1977-1980.

	Year							
	1977		1978		1979		1980	
Gear	Day	Night	Day	Night	Day	Night	Day	Night
Seine	7	0	3	2	10	0	250	2
Surface gill net	0	7	0	0	0	7	0	5
Bottom gill net	37	18	2	9	87	140	174	460
Trawl	193	199	1020	2085	1755	3714	3467	4576
Total catch	237	223	1025	2096	1852	3861	3891	5043
% of Total	52%	48%	33%	67%	32%	68%	44%	56%
Total yearly catch	460		3121		5713		8934	

During the 4-yr study period 1,738 unidentified Coregoninae were collected at beach and nearshore stations less than 3 m deep; 12,342 were collected at 6- and 9-m inshore stations and 4,124 at 12- and 15-m stations (Table 41). These numbers are biased due to differences in sampling gear used at each station. However, throughout the 4-yr period collections at stations 3 m or less were always less than those at deepwater stations 12 to 15 m, and deepwater station catches were always less than those at 6- and 9-m inshore stations (Table 41). During 1980 all sizes of unidentified Coregoninae were collected offshore, while collections inshore contained mostly small (less than 80 mm TL) Coregoninae (Fig. 63). The exceptions occurred in May and June, when a few larger individuals strayed inshore due to continued cool water temperatures there (Appendix 8).

Table 40. Length-frequency intervals (mm) of unidentified Coregoninae collected by each type of gear in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1977-1980.

	Year			
Gear	1977	1978	1979	1980
Seine	50-80	50-70	60-100	50-120
Surface Gill Net	130-280	----	110-130	120-190
Bottom Gill Net	150-290	110-240	90-240	100-310
Trawl	40-280	30-200	40-280	50-260
Total	40-290	30-240	40-280	50-310

Gonad condition evaluations revealed that approximately 13% of all fish collected in 1980 were male, 16% were female, 64% were immature and for 7% of the fish, gonad condition could not be determined. In 1979 and 1978 the respective gonad conditions were: 6% and 1.5% male, 8% and 0.5% female, 82% and 79% immature and for 4% and 19% of the fish, gonad condition could not be determined. The population of *Coregonus* spp. sampled in the vicinity of the J. H. Campbell Plant does not seem to be dominated by either sex, however, mature fish were not abundant until 1980.

Larval Coregoninae have been rare in samples collected near the J. H. Campbell Plant. Only one larva was collected in 1977, two in 1978 and eight in 1979. However, during 1980, 49 larval Coregoninae were recovered.

Difficulty in identifying species of the genus *Coregonus*, particularly individuals less than 180 mm, has been discussed (Jude et al. 1975, 1978). Apart from the easily identified *Coregonus clupeaformis*, the lake whitefish, other fish in the genus *Coregonus* caught in the vicinity of the J. H. Campbell Plant are believed to be bloaters, *Coregonus hoyi*. Due to problems with identification, some of these individuals may have been lake herring, *C. artedii*.

In the Great Lakes region *Coregonus hoyi* has been reported to spawn during February and March, usually in water deeper than 36 m (Scott and Crossman 1973). *Coregonus artedii* spawn between mid-November and mid-December

Table 41. Numbers of unidentified Coregoninae collected (various stations combined) in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1977-1980. Station depth is given in parentheses.

Station Groupings	Depth Range (m)	Year			
		1977	1978	1979	1980
<u>By transect</u>					
A(1.5 m),B(3 m)	1.5-3	36	319	298	811
C(6 m),D(9 m)	6-9	128	987	1508	2199
E(12 m),F(15 m)	12-15	216	522	1016	2370
L(6 m),N(9 m),U(6 m)	6-9	59*	1288	2881	3302
P(1 m),Q(1 m),R(1 m)	1	7	5	10	252
<u>By depth</u>					
A(1.5 m),B(3 m),P(1 m) Q(1 m),R(1 m)	1-3	43	324	308	1063
C(6 m),D(9 m),L(6 m) N(9 m),U(6 m)	6-9	187*	2275	4389	5501
E(12 m),F(15 m)	12-15	216	522	1016	2370
G(18 m),H(21 m)	18-21	14	-	-	-
Total number of fish collected		460	3121	5713	8934
% of total of all species of fish collected		0.59	3.42	7.31	10.62

*Stations N and U were not sampled.

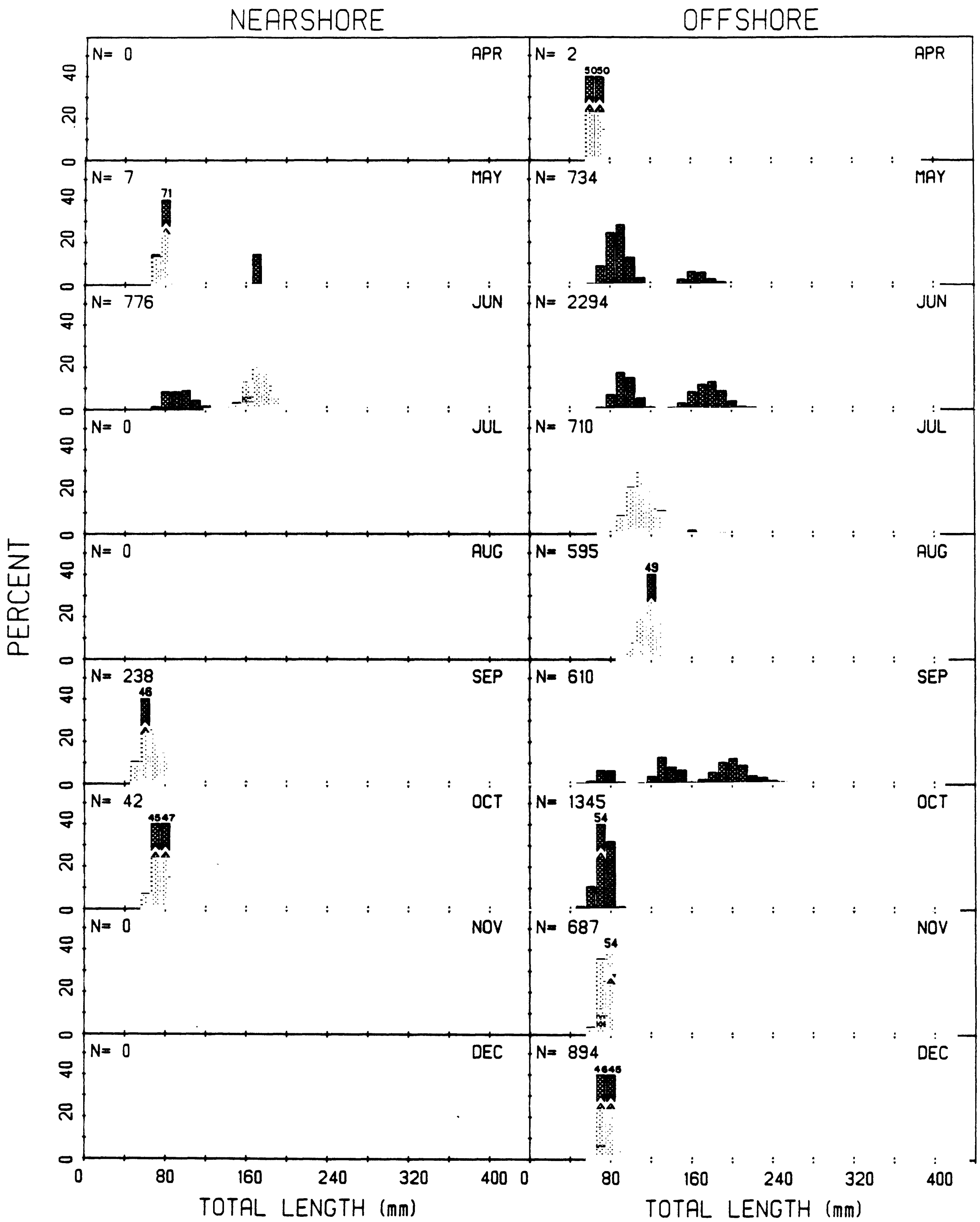


Fig. 63. Length-frequency distribution of unidentified Coregoninae collected by all gear at nearshore stations (beach,1.5 m, 3 m) and offshore stations (6-15 m) in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1980.

usually in shallow water less than 10 m (Koelz 1929). The small Coregoninae (60 to 90 mm) collected from September to December (Fig. 61) are most likely YOY *Coregonus hoyi*, resulting from early spring spawning. Since sampling for adult fish was not conducted in the early months of February and March, adults with well developed or spent gonads were not collected (Table 42).

Table 42. Gonad conditions of unidentified Coregoninae collected in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1980.

	Gonad Condition	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Slight development		26	245	5	2	62			
	Mod. development			52	1		58			
Males	Well developed			3						
	Ripe-running									
	Spent									
	Slight development		6	258	12	2	42		2	
	Mod. development			161	3		72			
Females	Well developed			3			4			
	Ripe-running									
	Spent			1						
	Absorbing									
Immature		2	336	481	240	188	257	373	190	226
Unable to distinguish			82	82	31	8	38			

Larvae--

Occurrence of larval Coregoninae during the 4-yr study has been rare. During 1977 and 1978 only three larval Coregoninae from 11 to 14.5 mm TL were collected. These were taken in June, at deepwater stations F (15 m, south) and W (15 m, north). In 1979 eight larval Coregoninae were caught, four in April at shallow water station A (1.5 m, south) and in Pigeon Lake (Jude et al. 1980) and four during July and August at stations 3 to 15 m. Those caught in April were large, 14 to 24 mm TL, while those obtained in July and August ranged from 11 to 13 mm TL. Jude et al. (1980) hypothesized that two species of *Coregonus* larvae were present, those collected in April possibly being *Coregonus clupeaformis* or *C. artedii*, while those collected in June, July and August were believed to be *Coregonus hoyi*. This is a reasonable conclusion since *C. clupeaformis* and *C. artedii* spawn in late fall; whereas, *C. hoyi* spawn in early spring. Eggs of *C. hoyi* therefore hatch later and larvae grow more slowly than those of *C. clupeaformis* or *C. artedii* which were spawned and hatched earlier. During 1980, there were again two groups of *Coregonus*

larvae. In April, 45 larval Coregoninae, averaging 13.2 mm TL, were collected from all three beach stations at temperatures of 4.4 to 13.8 C. Four others, taken in June and July, were only 12.2 to 13.5 mm TL and were taken at water temperatures between 12.2 and 25.1 C. Larvae taken in April were believed to be either *C. clupeaformis* or *C. artedii*, while the four captured later in the year were most likely *C. hoyi*.

Young-of-the-Year--

As previously mentioned small individuals (60 to 100 mm) collected from September to December were most likely YOY *C. hoyi* (Fig. 61). Lengths of YOY collected during these months have remained fairly consistent throughout the 4-yr period (Table 43), even though water temperature and abundance varied. YOY Coregoninae were most susceptible to seines and trawls and were captured at all stations, beach to 15 m. YOY were most often caught when water temperatures were between 5 and 17 C.

Table 43. Average total length (mm) and standard error of YOY Coregoninae collected in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan 1977 to 1980. Sample size is given in parentheses.

	Month			
Year	September	October	November	December
1977	73±1.74 (27)	70±0.59 (234)	72±0.99 (61)	72±4.79 (4)
1978	71±4.23 (9)	77±0.22 (1666)	83±0.38 (475)	86±2.31 (18)
1979	75±0.42 (334)	75±0.40 (391)	77±0.28 (1430)	82±4.01 (9)
1980	67±0.29 (334)	72±0.19 (1387)	76±0.25 (687)	76±0.21 (894)

Yearlings--

Yearling unidentified Coregoninae have been observed during every year of the study and ranged in length from 85 to 150 mm (Fig. 61). These individuals were often caught from June to September usually in bottom gill net sets and trawl hauls predominantly in 6 to 15 m of water. Water temperatures at time of capture were usually between 3 and 21 C.

Adults--

Age-2+ fish (age assigned using length-frequency histograms) ranged in length from 160 to 210 mm. These fish were captured in both surface and bottom gill net sets as well as trawl hauls at all stations. Fish older than 2 yr, most probably mature adults, ranged from 210 to 320 mm TL (Fig. 61). These fish were almost exclusively caught in bottom gill nets set at stations

6 m or deeper, usually during either June or September, and most often at water temperatures between 6 and 19 C. Adult Coregoninae were noticeably absent from catches during 1978 and 1979 (Fig. 61), which could be due to poor survival of the 1975 and 1976 year classes. The commercial fishery for this species was closed in 1976. Over the 4-yr period year classes were easily followed by using length-frequency data. Close examination revealed that fish collected in May 1978 and 1979 and April 1980 did not fit a consistent growth pattern, since YOY individuals caught in December were smaller than yearlings observed the following May or June. Unidentified Coregoninae collected in April 1980 were also much smaller than those observed the previous December. These individuals are not abundant, as only 15 have been collected over the 4-yr period; however, these smaller individuals may actually be YOY C. clupeaformis or C. artedii. These species, which spawn in late fall and whose eggs hatch in early spring, have been collected as larvae in April plankton net tows and also as YOY in April or May trawl hauls. These few fish may be stragglers from a population which utilizes cool water farther offshore.

Plant Effects--

Larvae--Few larval Coregoninae have been collected in the vicinity of the J. H. Campbell Plant over the past 4 yr; 11 were taken in 1977-1979 and 49 in 1980. Therefore plant operational effects upon larval populations of this family cannot be determined accurately. However, of the 49 larvae collected in 1980, most were collected in April with almost twice as many observed at the south reference beach station compared with the plant transect beach stations.

Juveniles and adults--Seines and surface gill nets were less effective at capturing unidentified Coregoninae than bottom gill nets or trawl hauls (Table 61), therefore only the latter two were compared for a determination of plant effects. Day and night trawl catches at 6- (C, L) and 9-m stations (D, N) showed a large increase in abundance of unidentified Coregoninae between 1978 and 1980 (Fig. 64). Bottom gill net data for 1980 (Fig. 65) do not show greater catches for stations in the vicinity of the plant, in fact, catches at station U (6 m, north discharge) were below those observed at reference station C (6 m, south). Catches during the day were, however, greater at the north transect in the vicinity of the plant than at the reference transect. ANOVA results for 1977-1980 showed that trawl catch of unidentified Coregoninae was significantly greater at the plant transect than at the reference area (Tables 44 and 45). This difference was most pronounced in 1979 when construction activity in the discharge area was at its peak (Fig. 66). Increased turbidity in the discharge area due to the construction may have decreased net avoidance, thus causing greater catches. Alternatively, Coregoninae may have been attracted to the discharge by organisms made more available to fish in the water column by the construction activity. Note that trawl catches mainly include YOY and yearlings.

Summary--Although the unidentified Coregoninae catch has increased significantly from 1977 to 1980, construction and operation of the J. H. Campbell Plant has affected the distribution and abundance of the species in

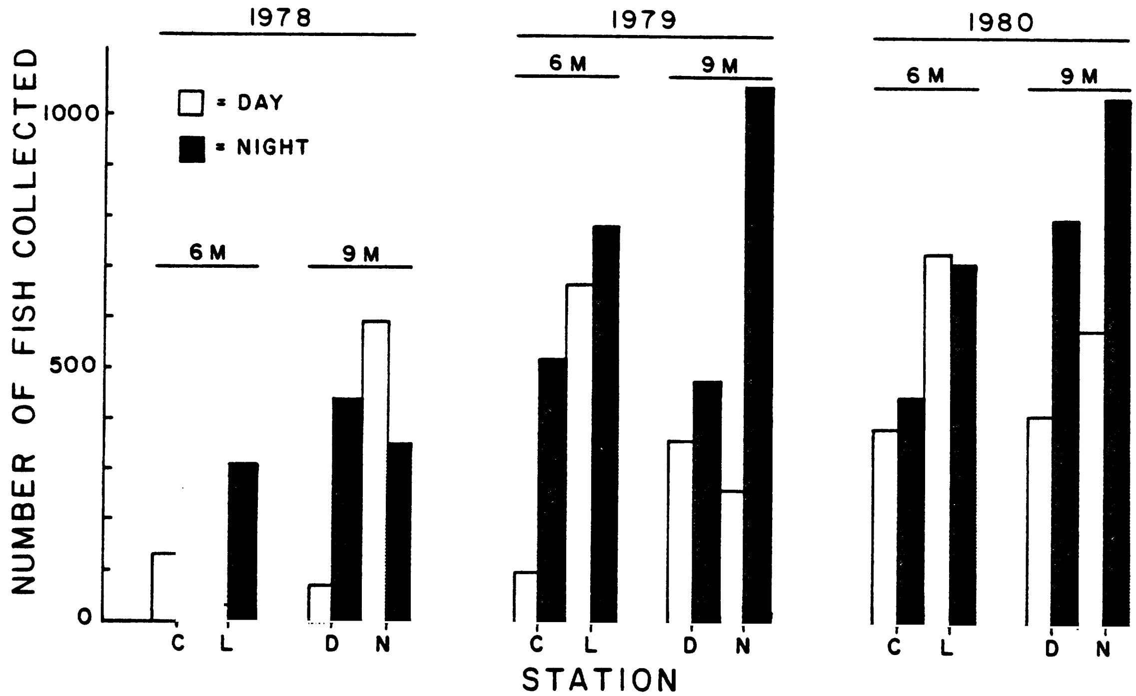


Fig. 64. Total number of unidentified Coregoninae caught in trawl hauls (pooled over months) at reference stations C (6 m, south) and D (9 m, south) and plant-affected stations L (6 m, north) and N (9 m, north) during the day and night in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1978-1980.

the immediate vicinity of the plant. However, this effect does not seem to have produced an adverse impact on local unidentified Coregoninae populations. Strong year classes, evidenced by the abundance of YOY during September to December, have been produced each year and subsequent survival of these year classes has also been documented. During 1980 mature adult Coregoninae appeared in the area, which is the first time this occurred since 1977. Unidentified Coregoninae were caught most often at depths of 6 to 9 m, particularly at night. Catches of larval Coregoninae have also increased from a low in 1977-1978 of 3 to a high of 45 in 1980.

<u>Yellow Perch</u>

Introduction--

Yellow perch is a widespread and highly adaptable percid fish, occurring throughout most of North America. In Lake Michigan, yellow perch are most abundant in protected bays, notably Green Bay, and are moderately abundant along the shoreline at depths less than 40 m (Wells and McLain 1973).

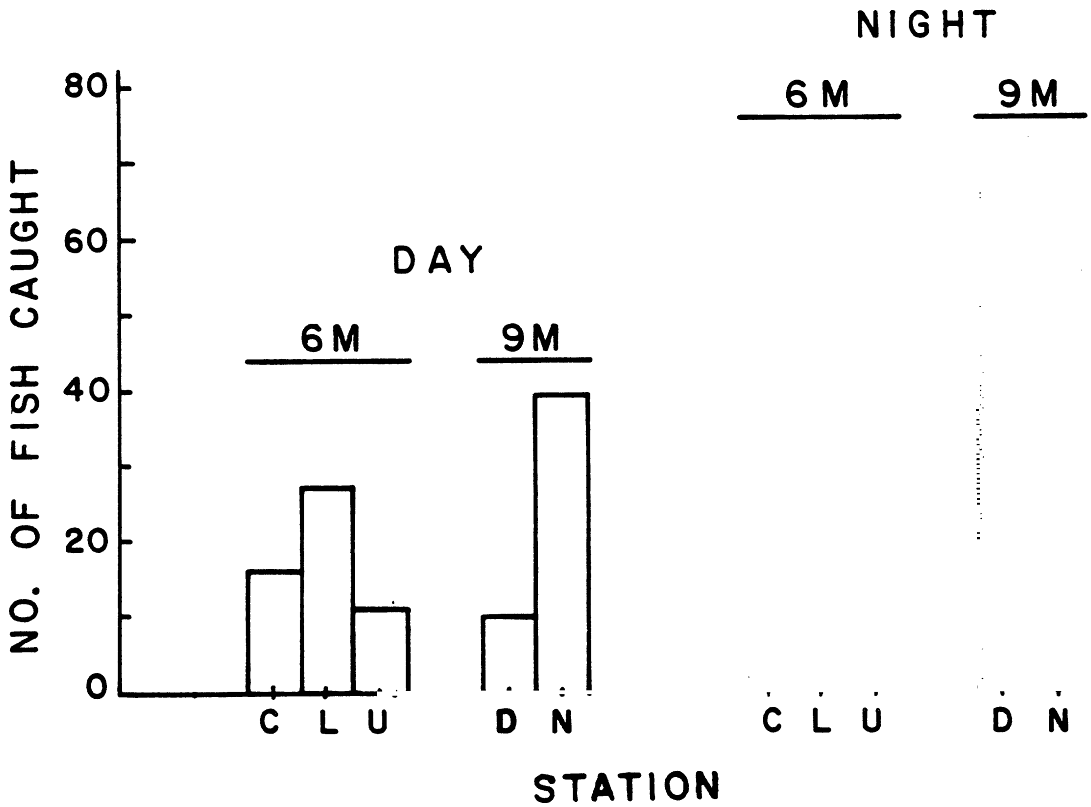


Fig. 65. Total number of unidentified Coregoninae caught in bottom gill net sets (pooled over months) at reference stations C (6 m, south) and D (9 m, south) and plant-affected stations L (6 m, south discharge), U (6 m, north discharge) and N (9 m, north) during the day and night in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1980.

Yellow perch have been important in Lake Michigan as a commercial species since the 1880s and as a sport fish since at least the 1920s (Wells 1977). Yellow perch abundance in Lake Michigan declined abruptly in the early and mid-1960s due to displacement and interference by alewife and due to an intensive fishery (Wells 1977). Perch populations increased in some areas of the lake during the 1970s (Wells 1977). Seasonal depth distribution of yellow perch in east-central and southeastern Lake Michigan has been described by Wells (1968), Brazo et al. (1975) and Jude et al. (1975, 1978, 1979a, 1979b, 1980).

During our 4-yr study in Lake Michigan near the J. H. Campbell Plant, yellow perch was the fourth-most abundant species captured in adult sampling gear during 1977, while during 1978, 1979 and 1980, perch were sixth in abundance. Total yearly catch of yellow perch ranged from 605 to 1715 fish

Table 44. Analysis of variance summary for unidentified Coregoninae caught in trawls at stations C (6 m, south) and L (6 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1977 through 1980. Data for June through November were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	3	4.9421	57.0422	<0.0001**
Month	5	3.7228	42.9690	<0.0001**
Station	1	1.0683	12.3302	0.0007**
Time	1	3.9996	46.1637	<0.0001**
Y x M	15	2.1017	24.2585	<0.0001**
Y x S	3	0.6458	7.4537	0.0002**
M x S	5	0.4004	4.6217	0.0008**
Y x T	3	0.8769	10.1208	<0.0001**
M x T	5	0.6507	7.5099	<0.0001**
S x T	1	0.6708	7.7428	0.0065*
Y x M x S	15	0.4132	4.7687	<0.0001**
Y x M x T	15	0.3590	4.1441	<0.0001**
Y x S x T	3	0.2479	2.8616	0.0408
M x S x T	5	0.2021	2.3329	0.0480
Y x M x S x T	15	0.2583	2.9810	0.0006**
Within cell error	96	0.0866		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

representing 0.8 and 2.0% respectively of the total yearly Lake Michigan collections. Yellow perch larvae were generally present in Lake Michigan field samples from May through August.

Larvae--

Yellow perch eggs generally incubate in approximately 10 days and larvae are about 5 mm at hatching (Scott and Crossman 1973). Young perch usually grow beyond the yolk-sac stage in about 5 days and are demersal at about 30 mm (Wong 1972). Larval perch swim well relative to other fish, and exhibit notable ability to avoid larval sampling devices at lengths exceeding 9 mm (Houde 1969; Jude et al. 1980).

Seasonal distribution--

May--Sampling was not performed during May 1977, but during mid-May 1978-1980, yellow perch larvae were collected at densities considerably greater than at any other time of a given year (Figs. 69-78). Mean lengths of fish sampled in May (5.7-7.2 mm) indicated that these perch were spawned in early May. Perch spawning in early May does not generally occur in cold Lake Michigan water but does occur in warmer waters of inland lakes, rivers and streams, some of which run into Lake Michigan. Perch larvae sampled in mid-

Table 45. Analysis of variance summary for unidentified Coregoninae caught in trawls at stations C (6 m, south), D (9 m, south), L (6 m, north) and N (9 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1978 through 1980. Data for June through November were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	2	1.8997	13.3865	<0.0001**
Month	5	5.5961	39.4348	<0.0001**
Area	1	2.1497	15.1486	0.0002**
Depth	1	6.2450	44.0070	<0.0001**
Time	1	11.8938	83.8132	<0.0001**
Y x M	10	3.0556	21.5323	<0.0001**
Y x A	2	0.7992	5.6317	0.0044*
M x A	5	0.7068	4.9804	0.0003**
Y x D	2	0.4491	3.1644	0.0452
M x D	5	0.7016	4.9438	0.0003**
A x D	1	0.1643	1.1577	0.2837
Y x T	2	1.4033	9.8885	0.0001**
M x T	5	1.0213	7.1970	<0.0001**
A x T	1	0.9198	6.4814	0.0120
D x T	1	0.4672	3.2921	0.0717
Y x M x A	10	0.8671	6.1104	<0.0001**
Y x M x D	10	0.5683	4.0049	0.0001**
Y x A x D	2	0.5271	3.7142	0.0267
M x A x D	5	0.2794	1.9692	0.0867
Y x M x T	10	0.6306	4.4435	<0.0001**
Y x A x T	2	0.0546	0.3846	0.6814
M x A x T	5	0.2361	1.6636	0.1471
Y x D x T	2	0.3016	2.1256	0.1231
M x D x T	5	0.5681	4.0030	0.0020*
A x D x T	1	0.0736	0.5185	0.4726
Y x M x A x D	10	0.1382	0.9740	0.4687
Y x M x A x T	10	0.5690	4.0098	0.0001**
Y x M x D x T	10	0.1275	0.8982	0.5367
Y x A x D x T	2	0.3232	2.2778	0.1062
M x A x D x T	5	0.3029	2.1342	0.0647
Y x M x A x D x T	10	0.2309	1.6273	0.1043
Within cell error	144	0.1419		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

May in our study area probably originated from these inland waters (e.g., the Grand River, Pigeon Lake and Lake Macatawa) and were carried into Lake Michigan to our sampling area by currents (Jude et al. 1980).

Larvae were always most concentrated in water less than or equal to 3 m during May sampling, and highest mean densities (220-300/1000 m^3) for any given year were found at the south reference transect. The higher mean densities of yellow perch at the south transect might be expected since Pigeon

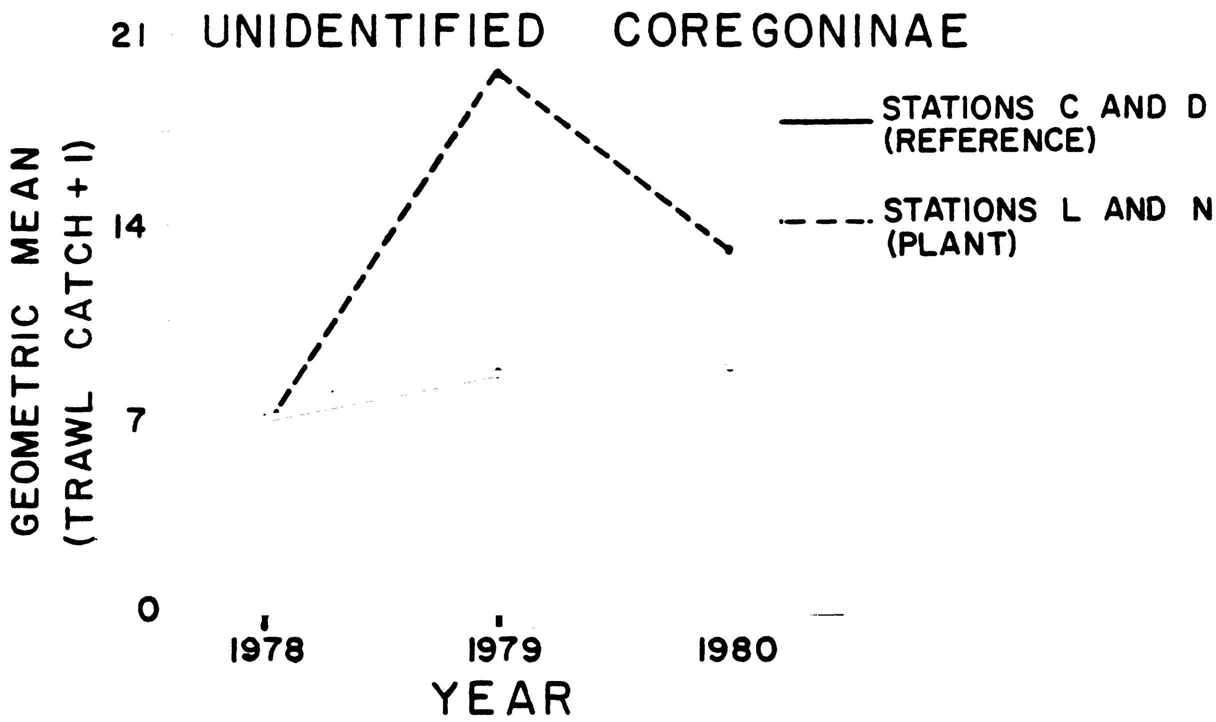


Fig. 66. Geometric mean number plus one of unidentified Coregoninae caught in trawls at stations C (6 m, south), D (9 m, south), L (6 m, north) and N (9 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1978 through 1980. Graph illustrates the YEAR x AREA interaction.

Lake, which is the closest potential inland spawning ground, is a well documented area for perch reproduction (Jude et al. 1978, 1979a, 1980, 1981a) and fish carried out from Pigeon Lake to Lake Michigan would likely be carried along the shoreline. Liston and Tack (1976) reported that current direction in Lake Michigan in the vicinity of the J. H. Campbell Plant was usually parallel to the shoreline (either north or south) and directions were sustained at times over several days. Currents from the north would sweep larvae from Pigeon Lake into our south reference transect where they would be vulnerable to our larvae sampling gear. Relatively warm water (12-14 C) occurred in the beach zone in May 1979, and comparatively high mean densities of perch larvae were collected (150/1000 m^3 from the north transect and 300/1000 m^3 from the south transect). Perch reproduction in Pigeon Lake was exceptional in 1979 (Jude et al. 1980) and probably contributed heavily to these high densities.

Early June--Abundance of yellow perch larvae in early June samples varied from year to year in our study. No perch larvae were collected during this period in 1977 (Figs. 67-68). Relatively low water temperatures (7-17 C) in

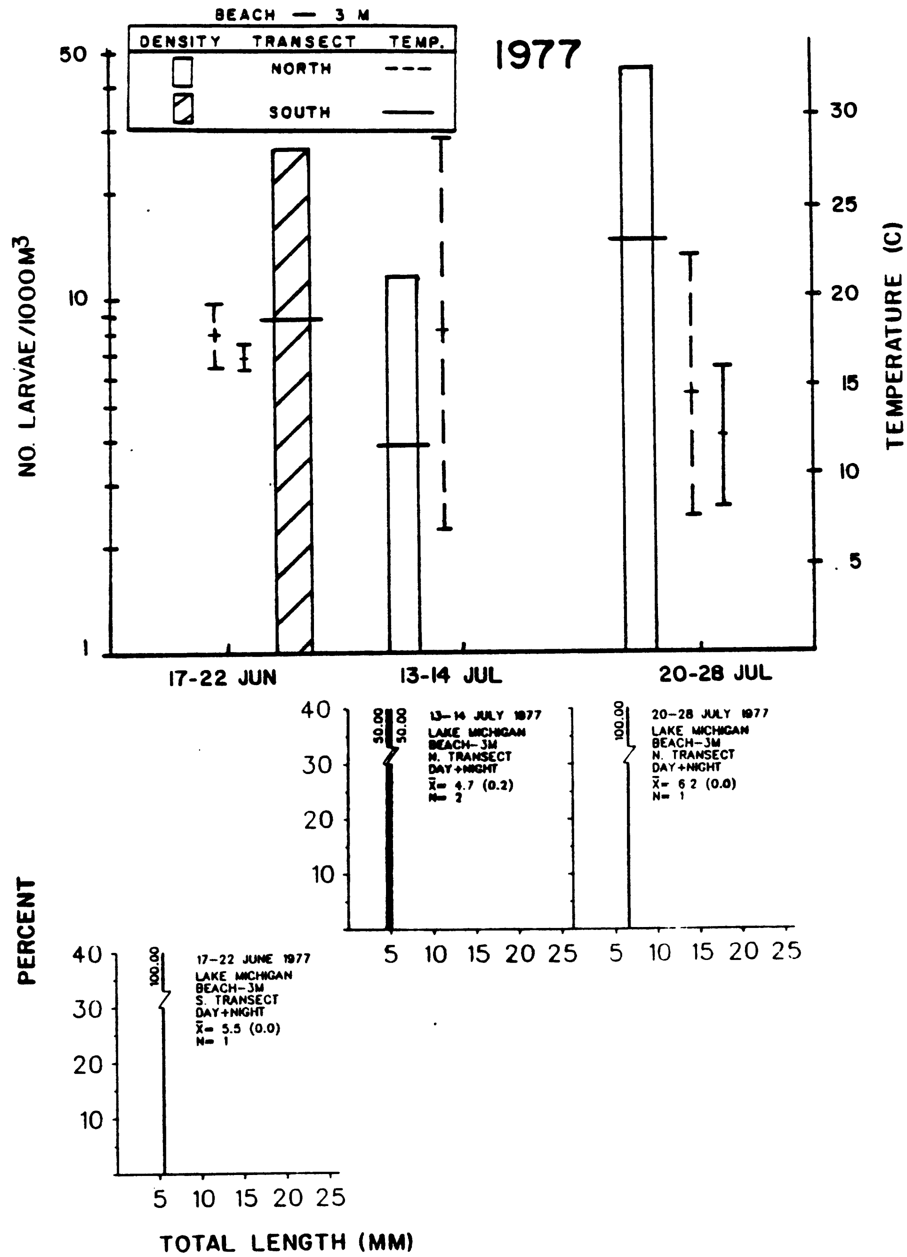


Fig. 67. Density (no./1000 M^3 plotted on log scale) of larval yellow perch collected during June to September 1977 at beach - 3 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

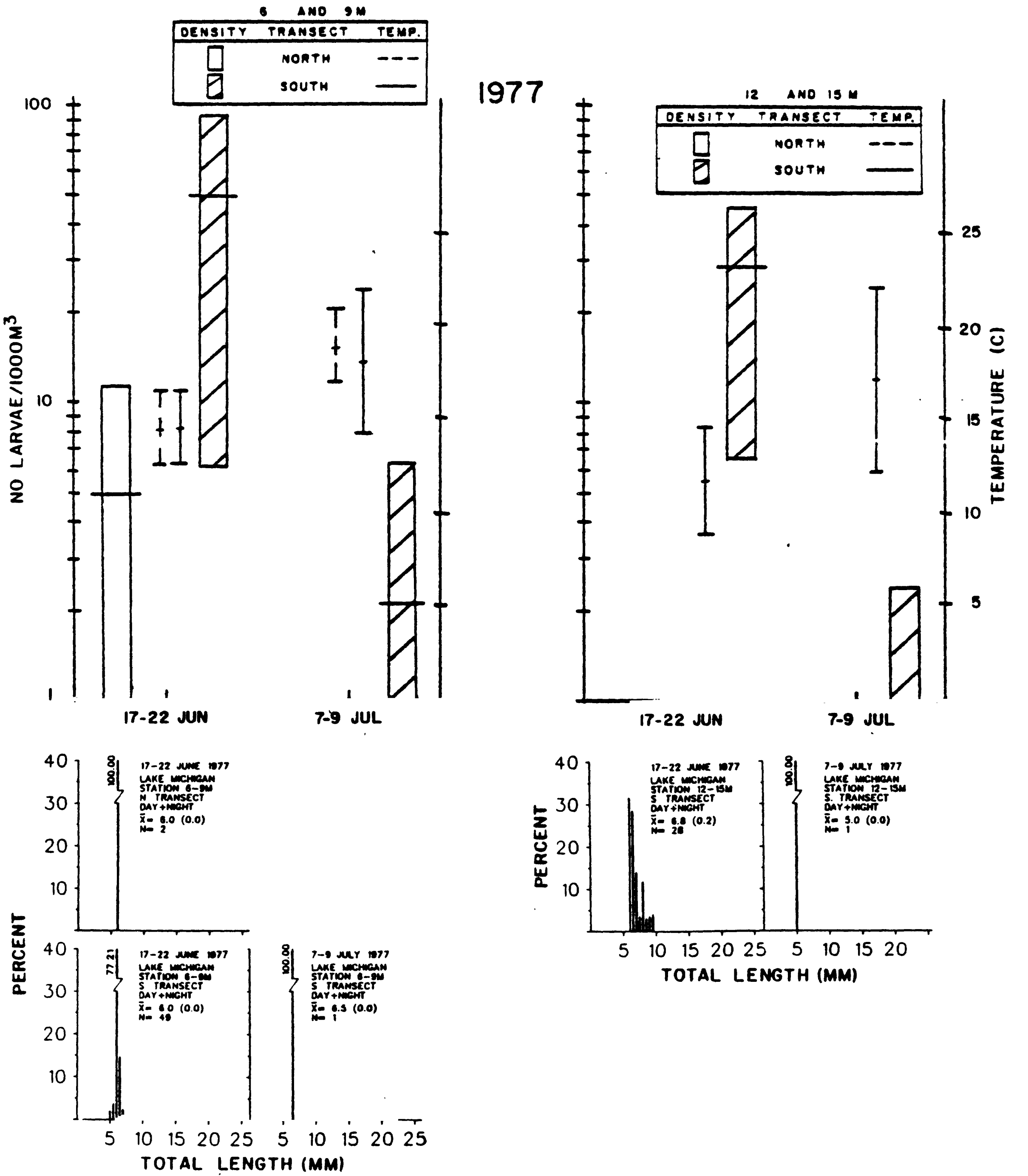


Fig. 68. Density (no./1000 M^3 plotted on log scale) of larval yellow perch collected during June to September 1977 at 6 and 9 m, 12 and 15 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

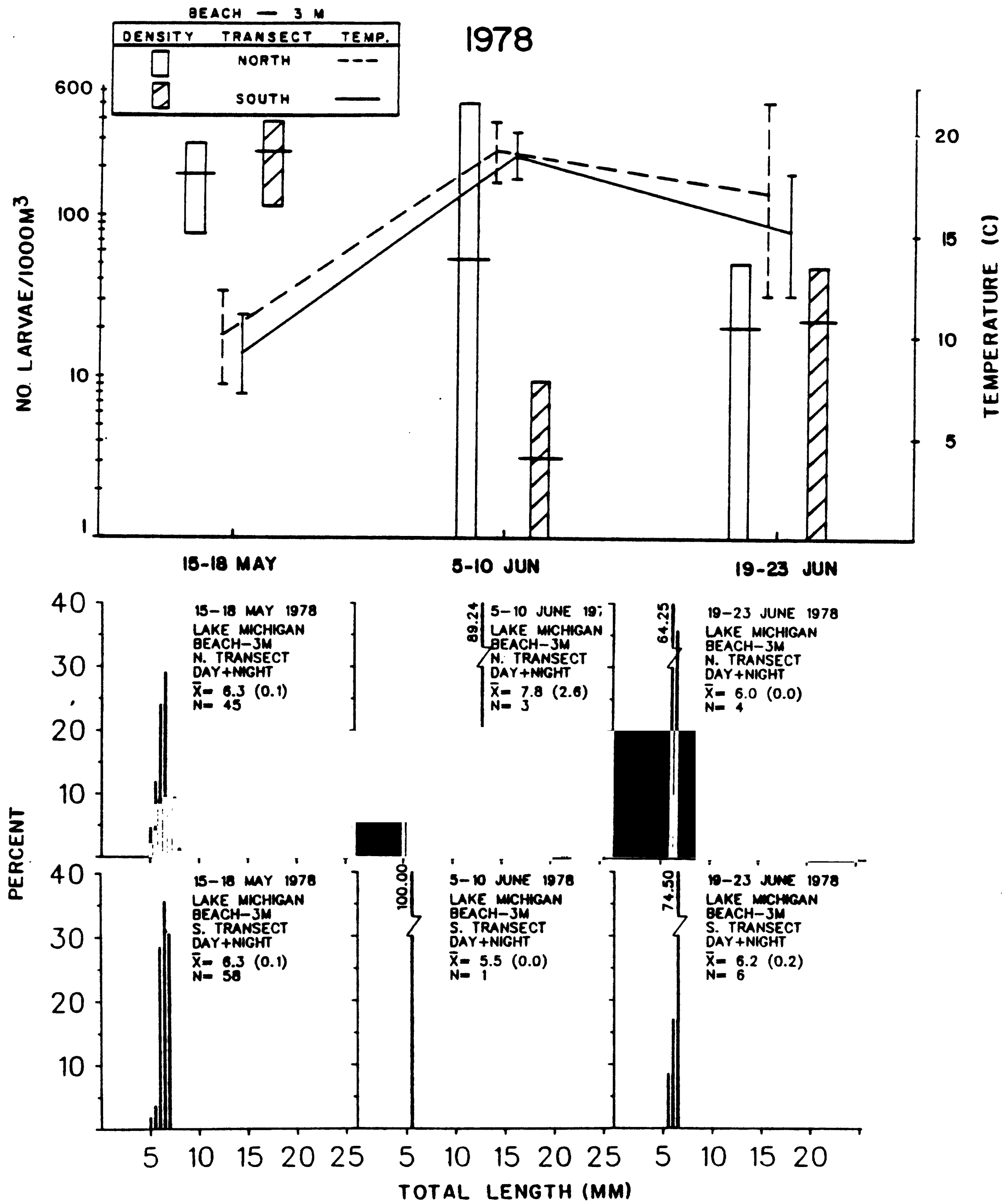


Fig. 69. Density (no./1000 M^3 plotted on log scale) of larval yellow perch collected during April to September 1978 at beach - 3 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

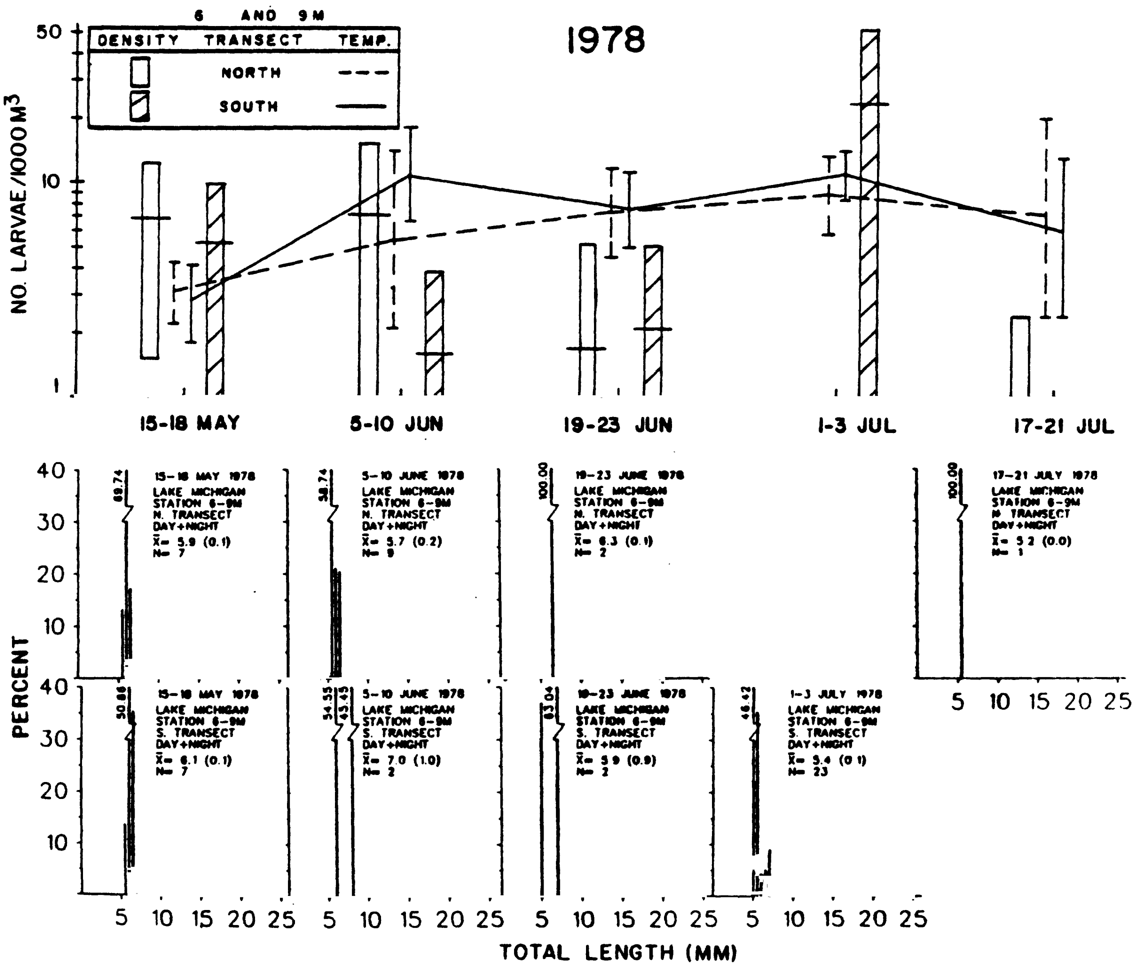


Fig. 70. Density (no./1000 M^3 plotted on log scale) of larval yellow perch collected during April to September 1978 at 6 and 9 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

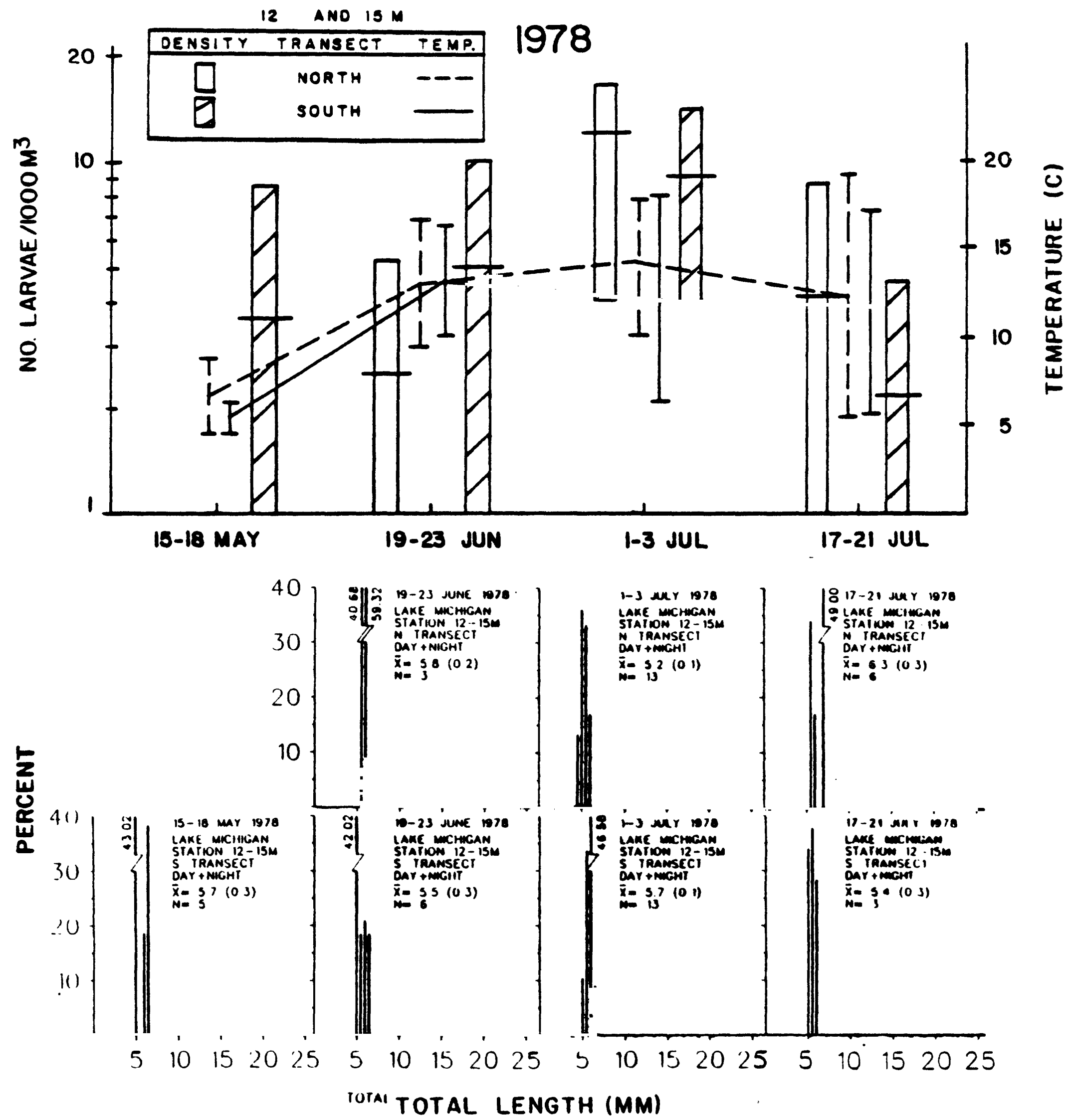


Fig. 71. Density (no./1000 M^3 plotted on log scale) of larval yellow perch collected during April to September 1978 at 12 and 15 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

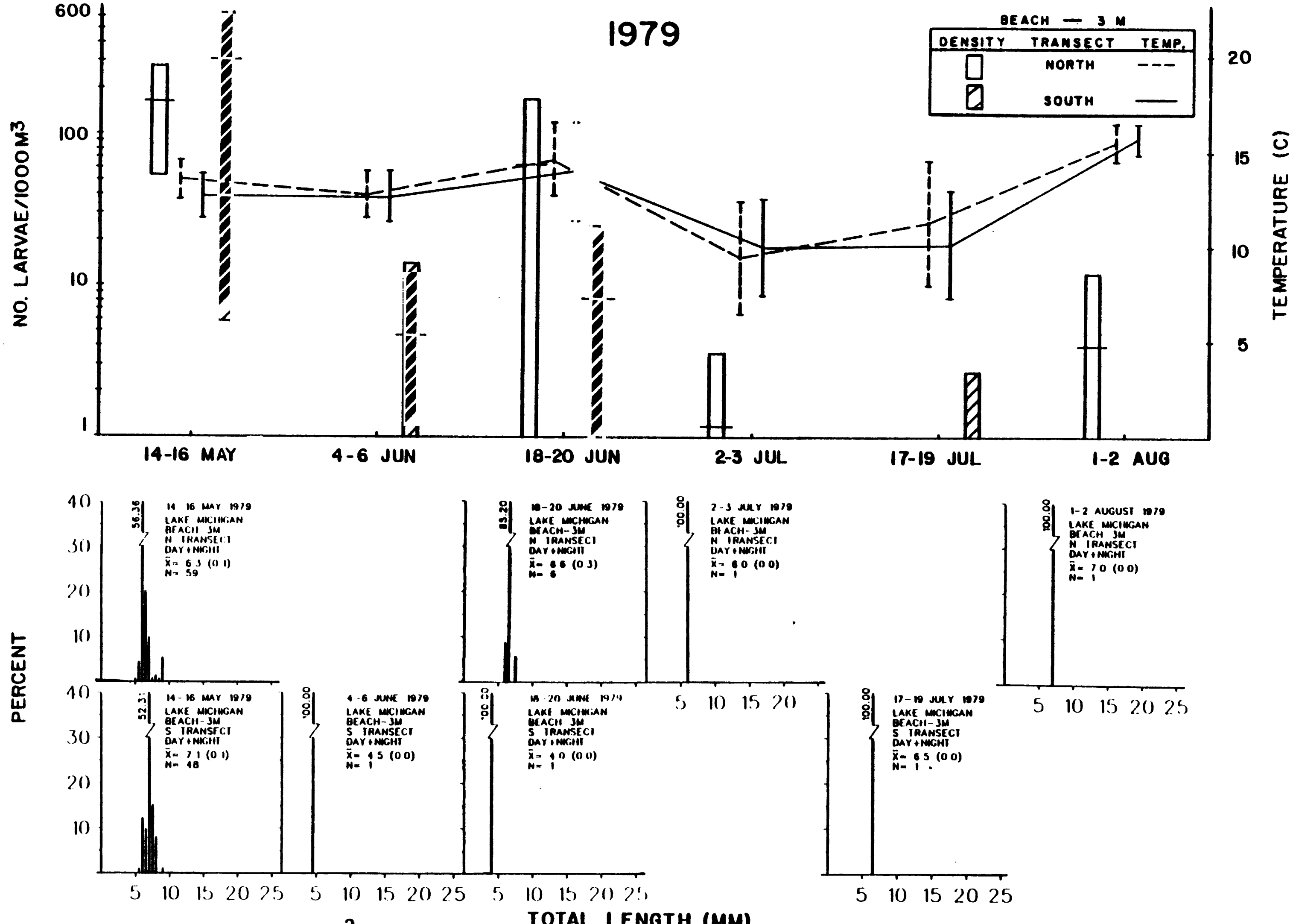


Fig. 72. Density (no./1000 M^3 plotted on log scale) of larval yellow perch collected during April to September 1979 at beach - 3 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

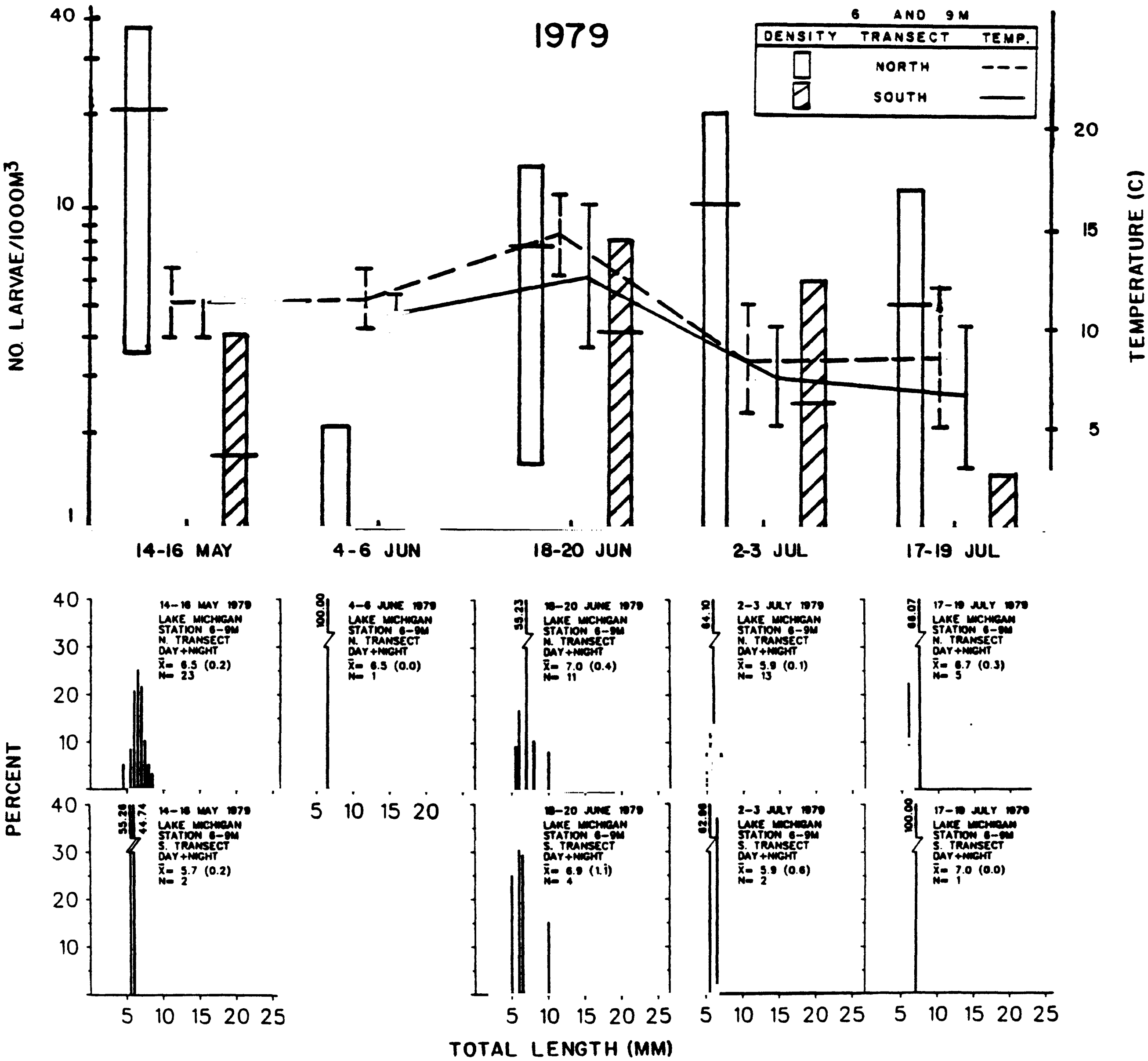


Fig. 73. Density (no./1000 M^3 plotted on log scale) of larval yellow perch collected during April to September 1979 at 6 and 9 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

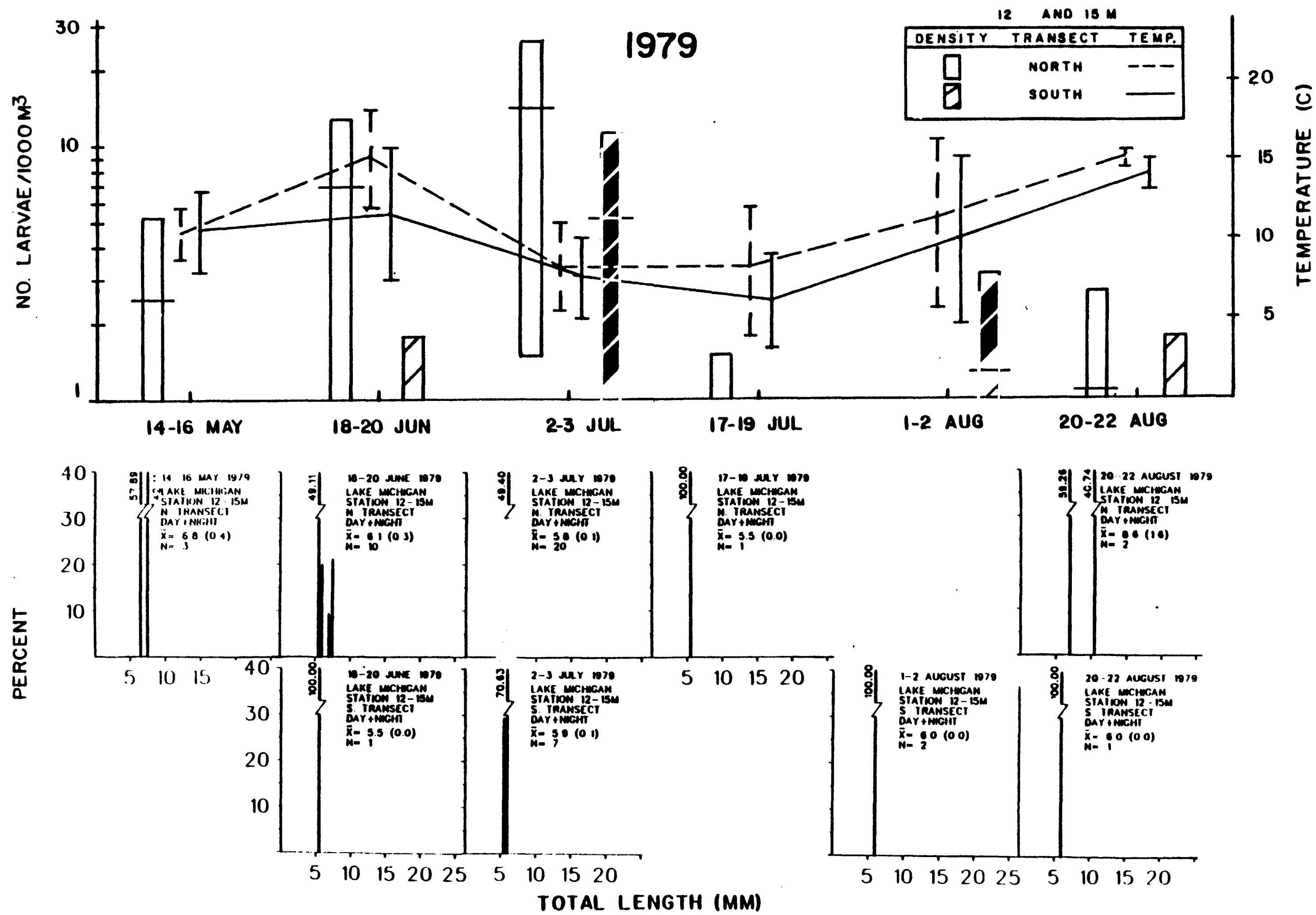


Fig. 74. Density (no./1000 M^3 plotted on log scale) of larval yellow perch collected during April to September 1979 at 12 and 15 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

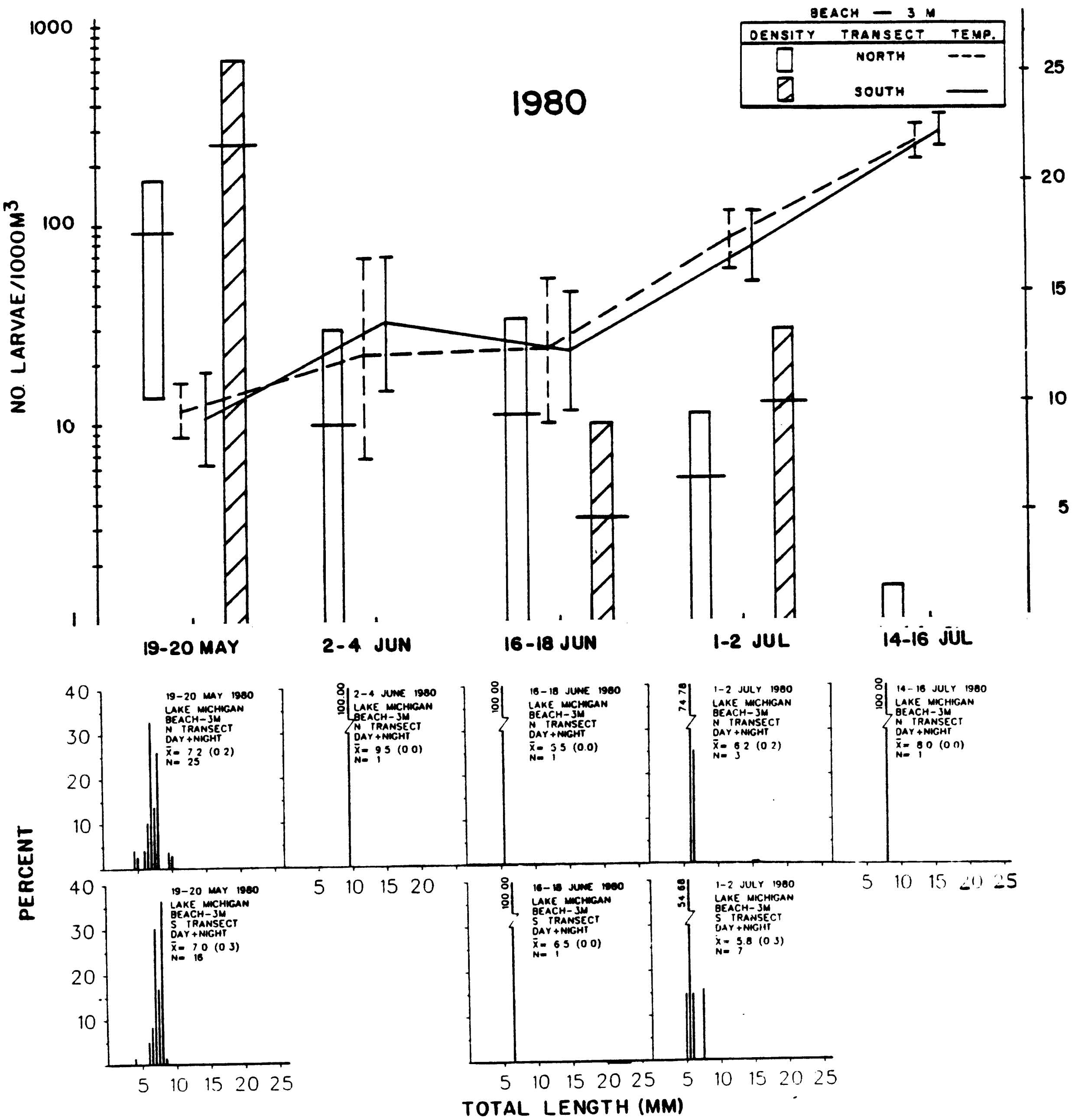


Fig. 75. Density (no./1000 M^3 plotted on log scale) of larval yellow perch collected during April to September 1980 at beach - 3 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

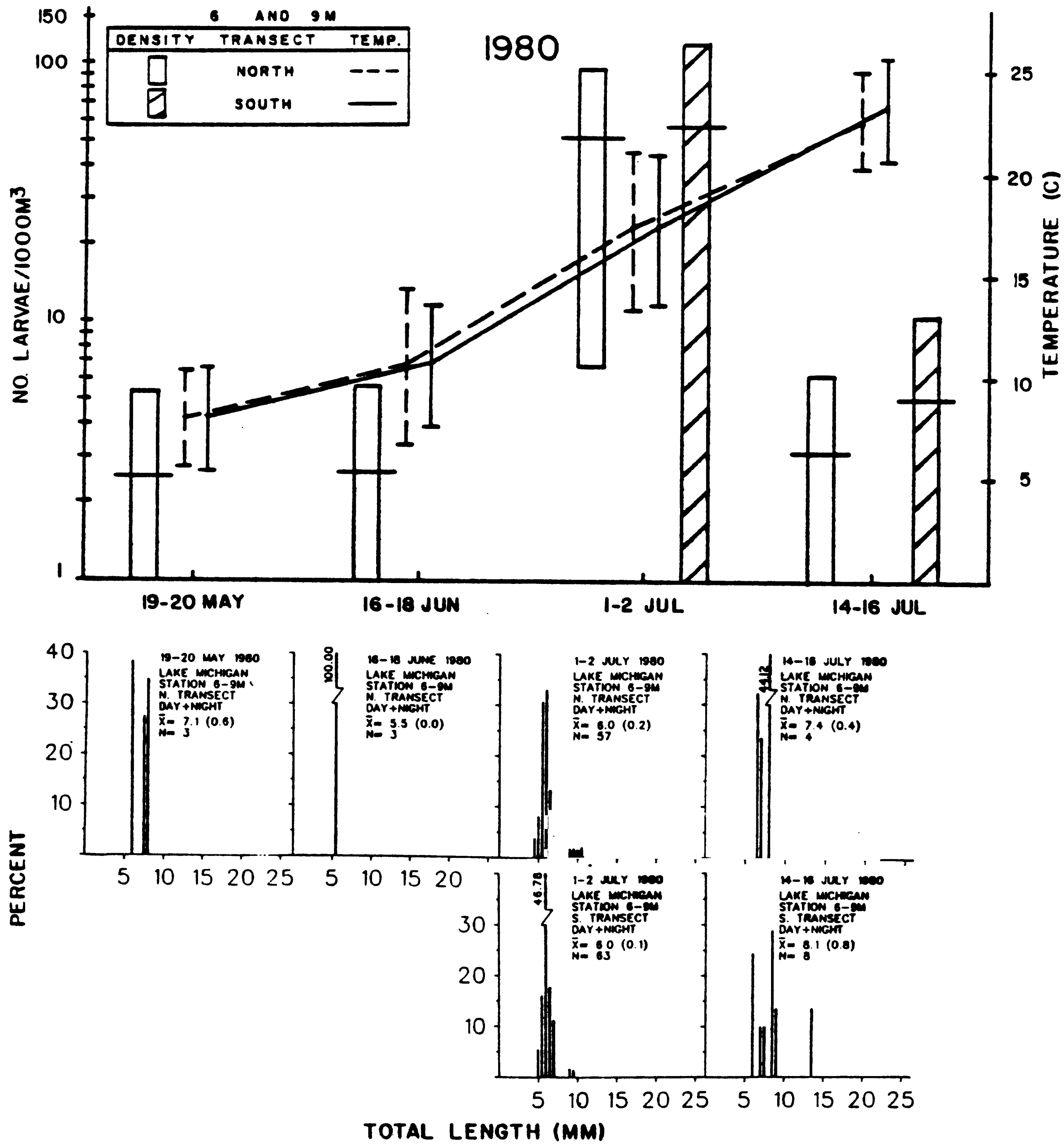


Fig. 76. Density (no./1000 M^3 plotted on log scale) of larval yellow perch collected during April to September 1980 at 6 and 9 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michgian. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

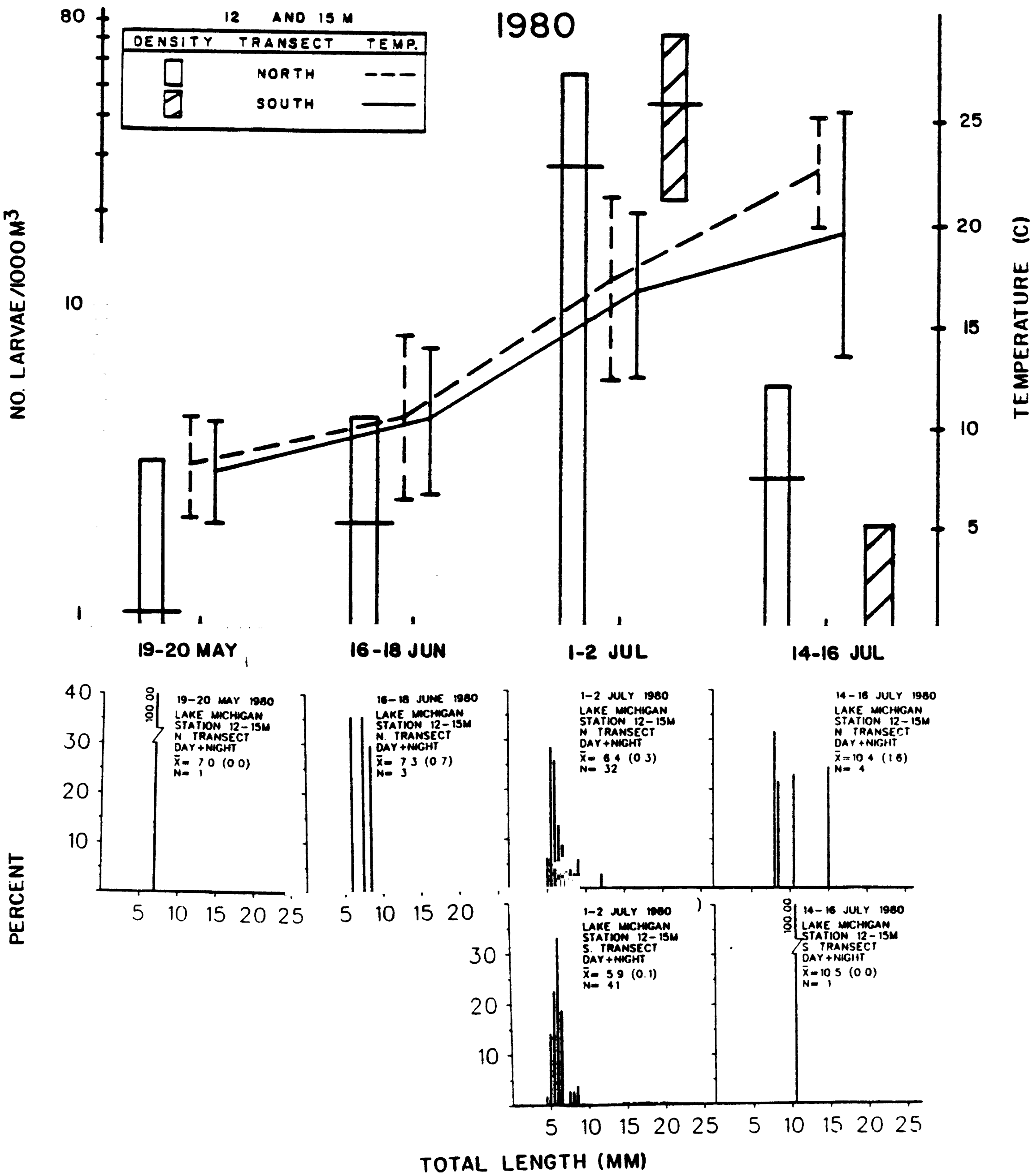


Fig. 77. Density (no./1000 M^3 plotted on log scale) of larval yellow perch collected during April to September 1980 at 12 and 15 m (all contours, depth strata and diel periods pooled) near the Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S.E. Midpoint of water temperature range (vertical line) at time of collection is shown. Length-frequency histograms for all larvae collected during each period are also shown. N = number of larvae collected, $\bar{x}$ = mean length of larvae, S.E. given in parentheses.

inshore water in 1977 probably delayed perch spawning until mid-June in Lake Michigan, and fish spawned in inland waters were apparently large enough by early June to avoid our sampling gear.

In contrast, unusually warm beach zone temperatures (17-21 C) in 1978 resulted in late May - early June spawning by yellow perch in Lake Michigan (Figs. 69-71). Perch larvae collected were represented by a combination of fish spawned in Lake Michigan (length less than 7.0 mm) and a few fish spawned in inland waters which ranged in length from 7.5 to 13.0 mm. Collection of a 13.0-mm larva was unusual, since perch larger than about 7.5 mm were generally able to avoid our nets.

Low mean densities (1 - 4.5/1000 m³) of perch larvae recently hatched in Lake Michigan were estimated from early June collections in 1979 (Figs. 67-77). As in 1977, perch spawned in early May were apparently large enough to avoid our nets.

A 9.5-mm yellow perch larva that was probably spawned in inland waters was collected on 2-4 June 1980 (Fig. 75). Our early June sampling period apparently preceded perch spawning in Lake Michigan in 1980 since no newly hatched larvae were collected.

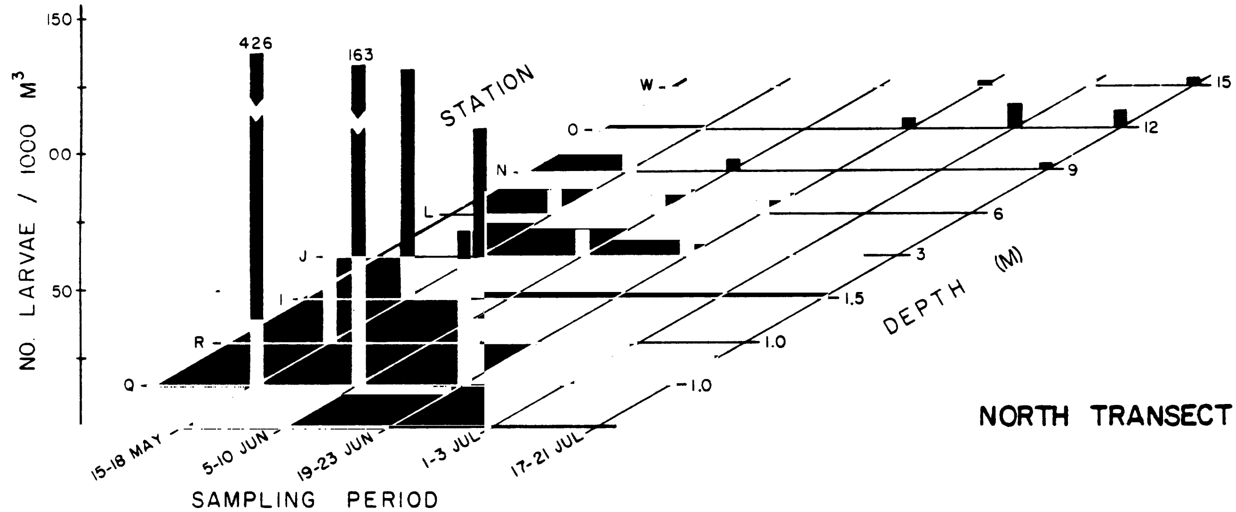
After the first sampling period of June 1980, perch that were spawned in early May and collected then in high densities were not collected in fish larvae sampling gear. Perch from this cohort were not caught again until August when they became vulnerable to adult and juvenile sampling gear.

Late June--Perch spawning in Lake Michigan generally occurs in late May - early June, and yellow perch larvae that were spawned in Lake Michigan were collected at relatively high densities during late June of each sampling year (Fig. 67-77). Mean length of perch ranged from 4.0 to 7.3 mm. Although larvae were distributed at all sampling depths, highest fish larvae densities occurred at contours less than or equal to 3 m during all years, except 1977. In 1977 perch larvae densities were highest at 6 and 9 m. Larvae were collected at both transects in all years, but in 1979 and 1980, fish larvae densities were greater at the north transect than at the south reference transect, perhaps because areas of riprap were available to spawning perch at the north transect during those years.

July--Length-frequency data for early and late sampling periods in July indicated that scattered perch spawning continued into late June (Fig. 67-77). Samples collected in July therefore included some newly hatched larvae along with larvae that were hatched in early June. Some fish from early June spawning were large enough in July to exhibit net avoidance behavior.

Yellow perch larvae densities were roughly comparable for July 1977-1979 despite the upwelling which occurred in July 1979. The effect of the upwelling upon perch YOY was not evident until August and September. During July of all 4 yr, larval perch densities were generally lowest in water 3 m deep or less.

1978



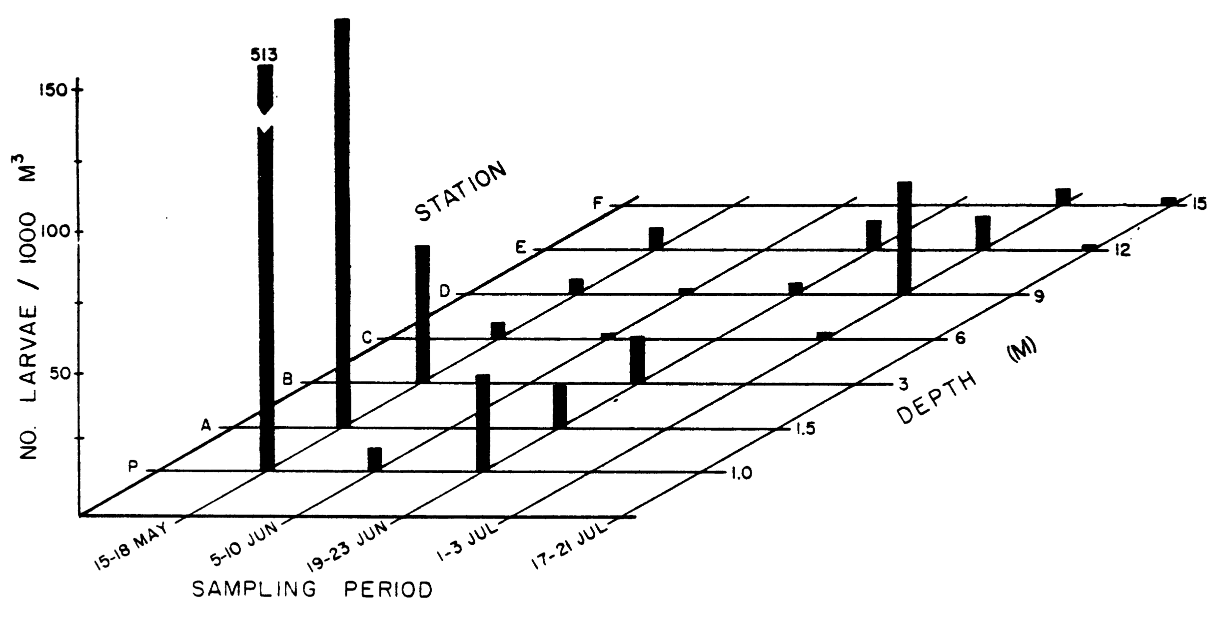
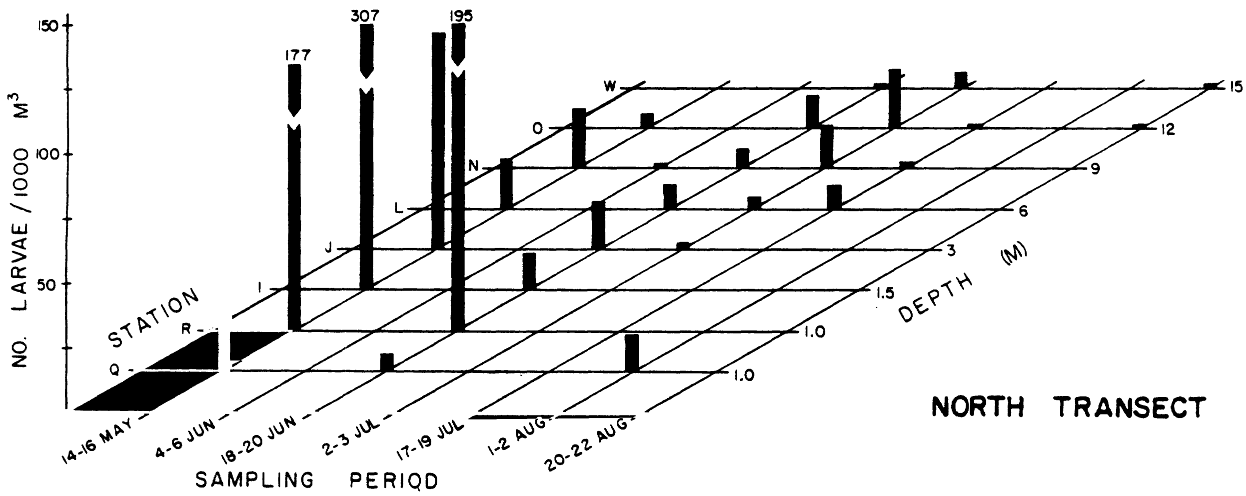


Fig. 78. Mean density (no./1000 m^3) of larval yellow perch for north and south transect stations in Lake Michigan near the J. H. Campbell Plant, 1978 to 1980. Mean densities were calculated by averaging densities over all gear (plankton nets and sleds), strata and diel periods (day and night) sampled.

1979



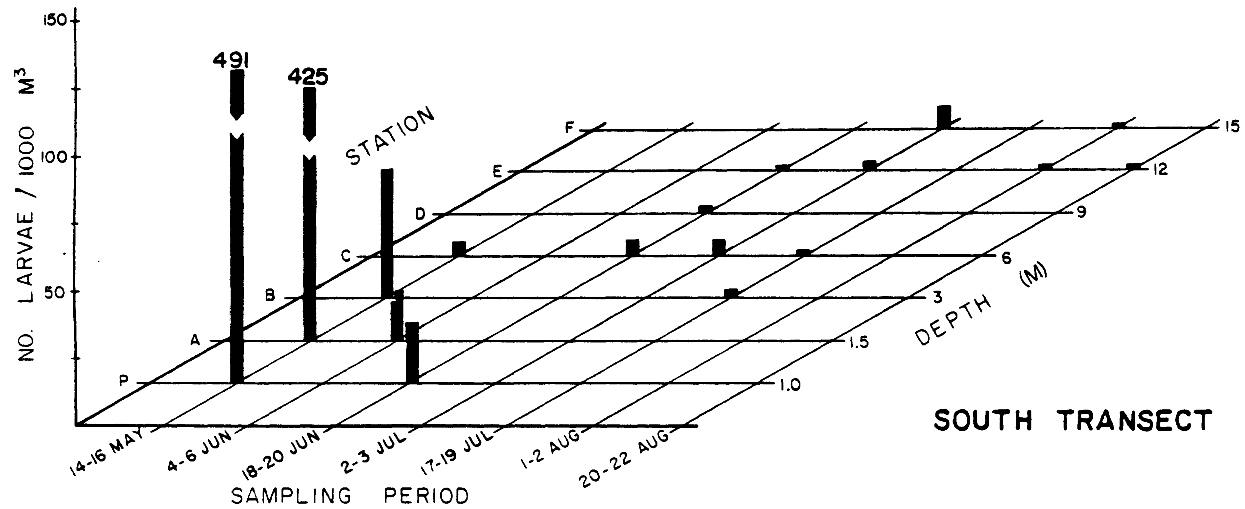
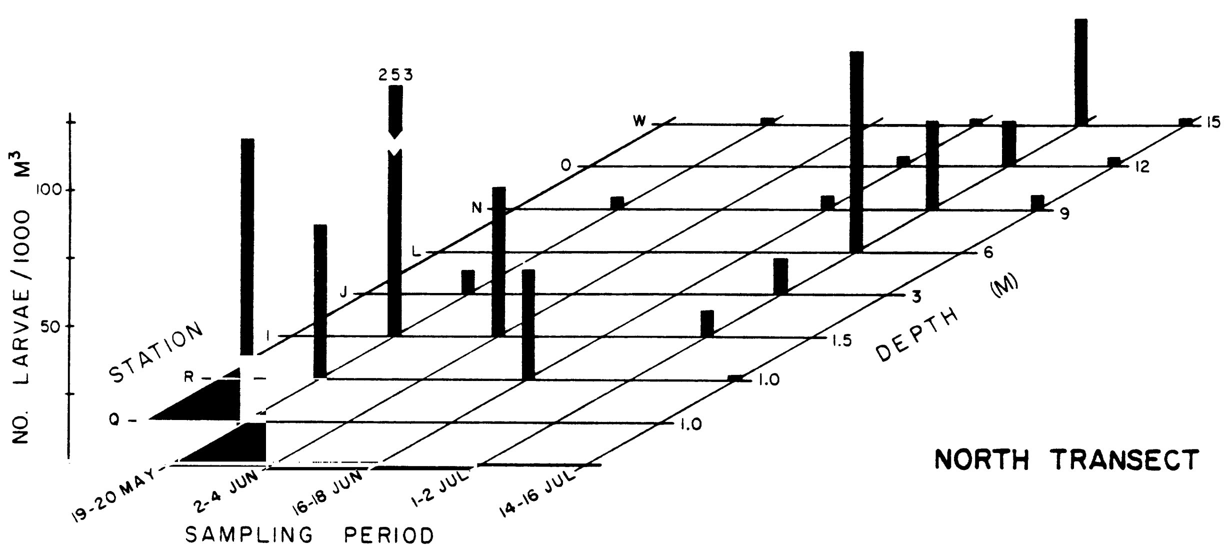


Fig. 78. Continued.

1980



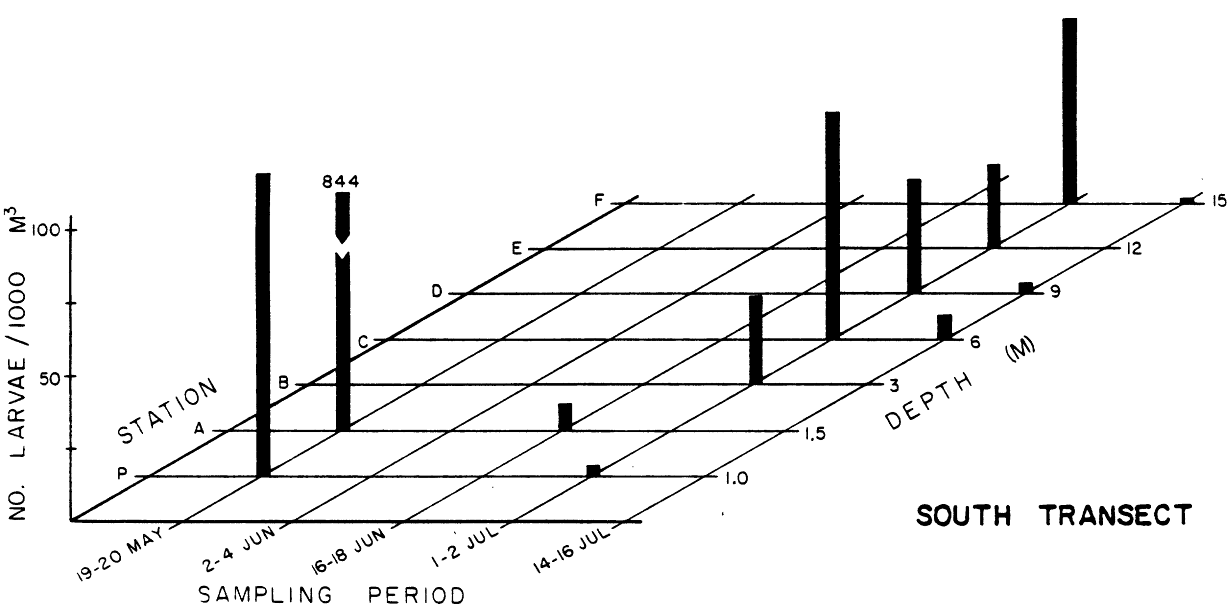


Fig. 78. Continued.

Water temperatures rose gradually but steadily from April through July 1980 (Fig. 22), and perch spawning may have been concentrated over a comparatively short time period in mid-June when temperatures were favorable. This would explain the relatively high mean densities (e.g., about 50/1000 m^3 at depths from 6 to 15 m) of yellow perch larvae estimated from samples collected in early July 1980.

August--During 4 yr of sampling, yellow perch larvae were collected in August only in 1979 (Figs. 67-77). In other years (1977, 1978 and 1980) a few YOY were caught in adult sampling gear (Fig. 79), but perch were able to avoid fish larvae sampling gear. Larvae collected in August 1979 were small relative to other years (6.0-10.5 mm) possibly due to the July upwelling which could have retarded perch growth. Net avoidance could also explain this finding.

Young-of-the-Year--

YOY comprised from 30 to 41% of the total number of yellow perch caught in trawls, seines and gill nets during the 4-yr study. Catch was lowest in 1979 (183 fish) when an upwelling and persistently low temperatures (Fig. 22) apparently limited perch reproductive success and perch catches in general. In contrast, 696 YOY perch were captured in 1980 when water temperatures were mild and no upwellings were observed.

Seasonal distribution--

July and August--Except for five perch (30- and 40-mm length interval) caught in July 1977, YOY were not vulnerable to adult sampling gear until August. In general YOY exhibited length modes at 30 and 60 mm. The upper end of this size range represents fish that were spawned during mid-May in major streams and lakes which flow into Lake Michigan (see RESULTS AND DISCUSSION, Yellow Perch, Larvae). These fish were probably carried to the sampling area from their nursery grounds by shoreline currents (Jude et al. 1980). Smaller fish captured in August were spawned in the inshore regions of Lake Michigan during late May or early June. Although YOY were caught at all sampling depths, most were caught from the beach zone to 9 m (Fig. 79). Catches of YOY in 1977 (62 fish) and in 1980 (224 fish) were notable. Perch fry also appeared in August larvae samples in 1978 and 1980 at densities from 16-53/1000 m^3. No YOY perch were caught during August 1979 probably due to cold water temperatures which limited YOY growth and numbers. Clady (1976) reported that survival of larval yellow perch is adversely affected when fish are exposed to a temperature of 10 C. Temperatures between 2.5 and 10 C were prevalent from July through early August in 1979.

September--By September a few YOY had grown into the 90-mm length interval. Fish distribution was still skewed towards shallower sampling depths (beach to 9 m) even though 109 perch (representing 28% of the YOY catch) were captured at 12 and 15 m in 1980. September catches of YOY were high in 1977 (283 fish), 1978 (268 fish) and 1980 (385 fish). Only one YOY

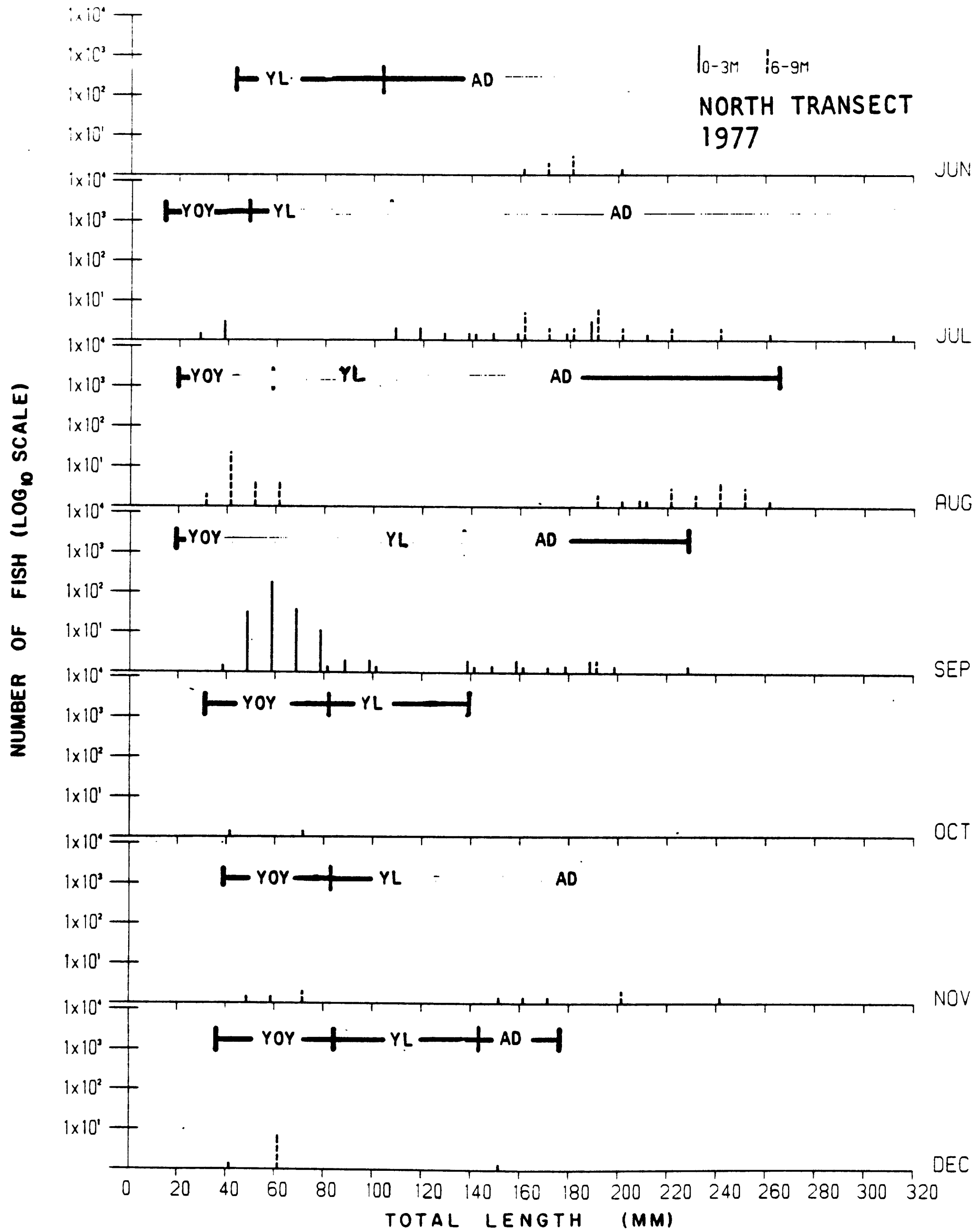


Fig. 79 . Length-frequency histograms for yellow perch collected during June - December 1977 and April - December 1978-1980 at north and south transects. Stations were combined into two groups for the north transect: beach and 3 m; 6 and 9 m and into three groups for the south transect: beach, 1.5 and 3 m; 6 and 9 m; and 12 and 15 m. Diel periods and gear types were pooled. YOY = Young-of-the-year; YL = Yearling; AD = Adult.

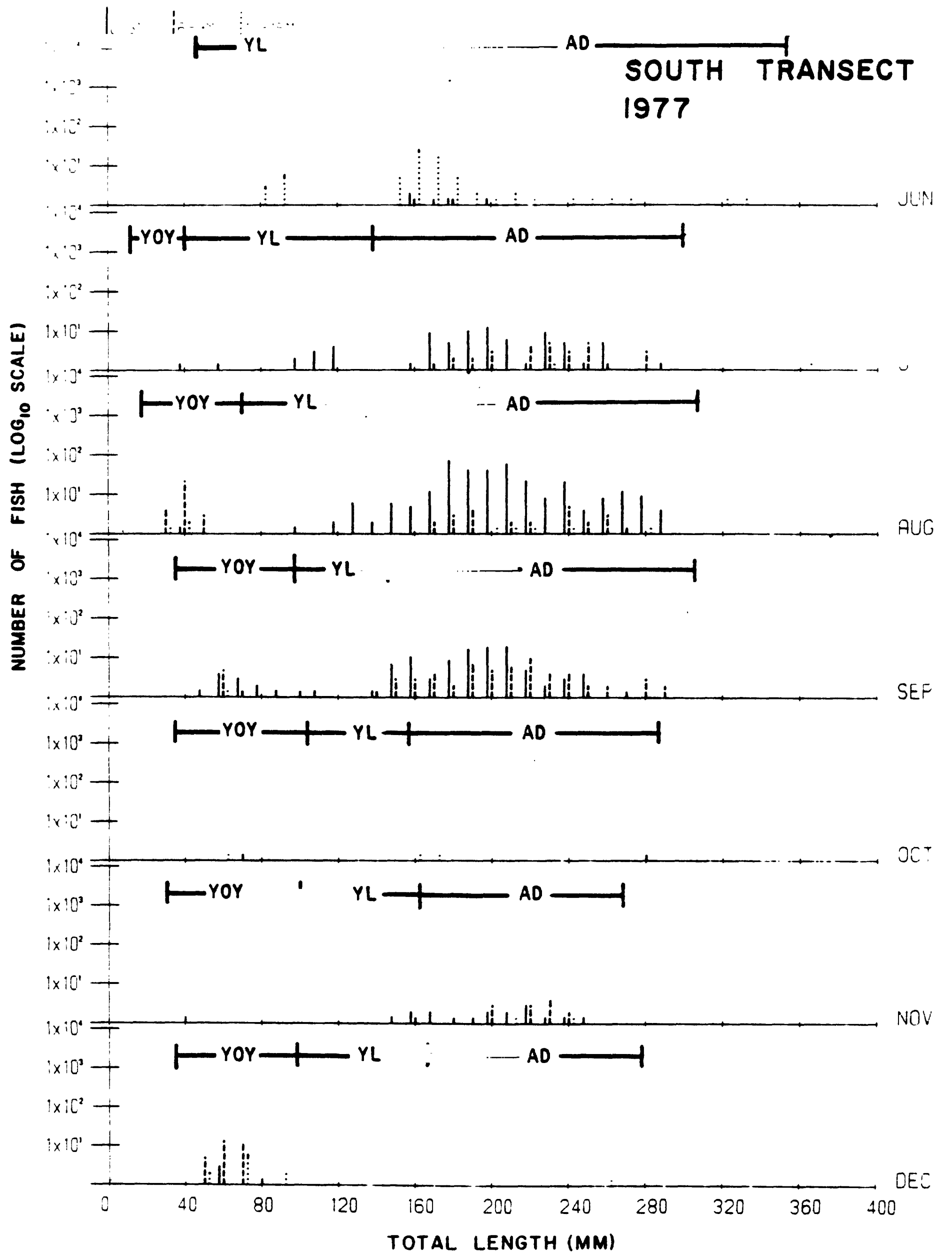
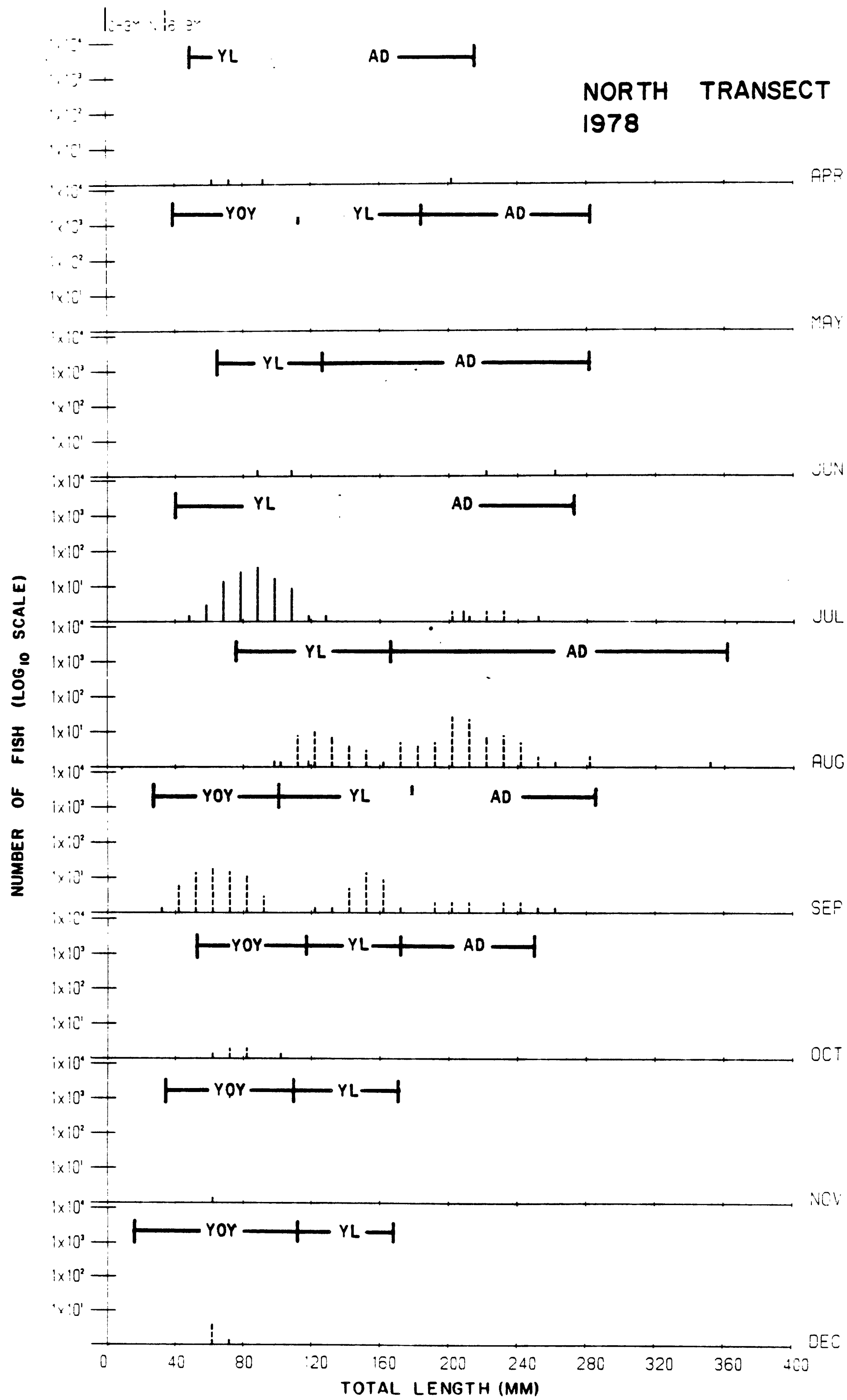


Fig. 79 . Continued.



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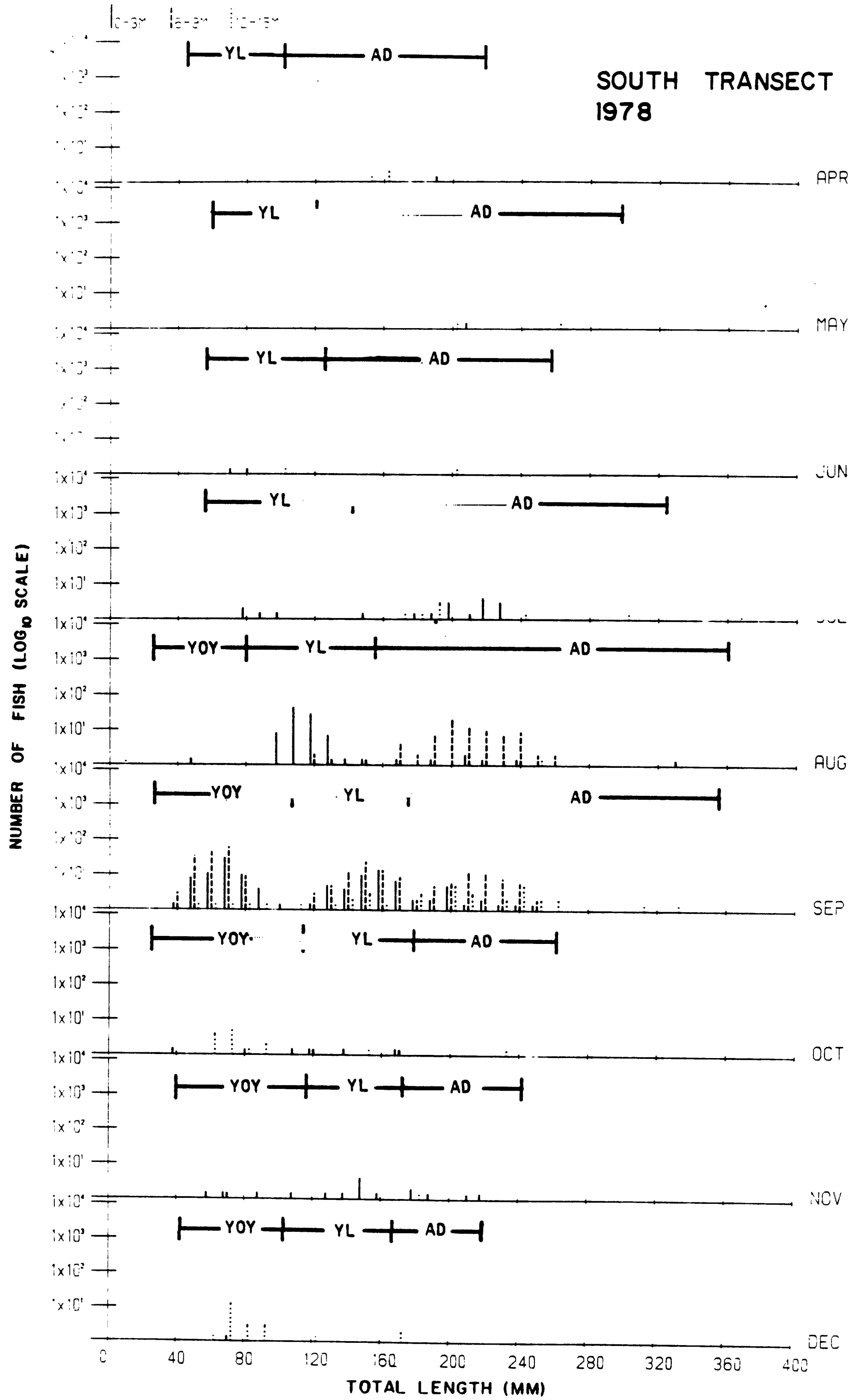

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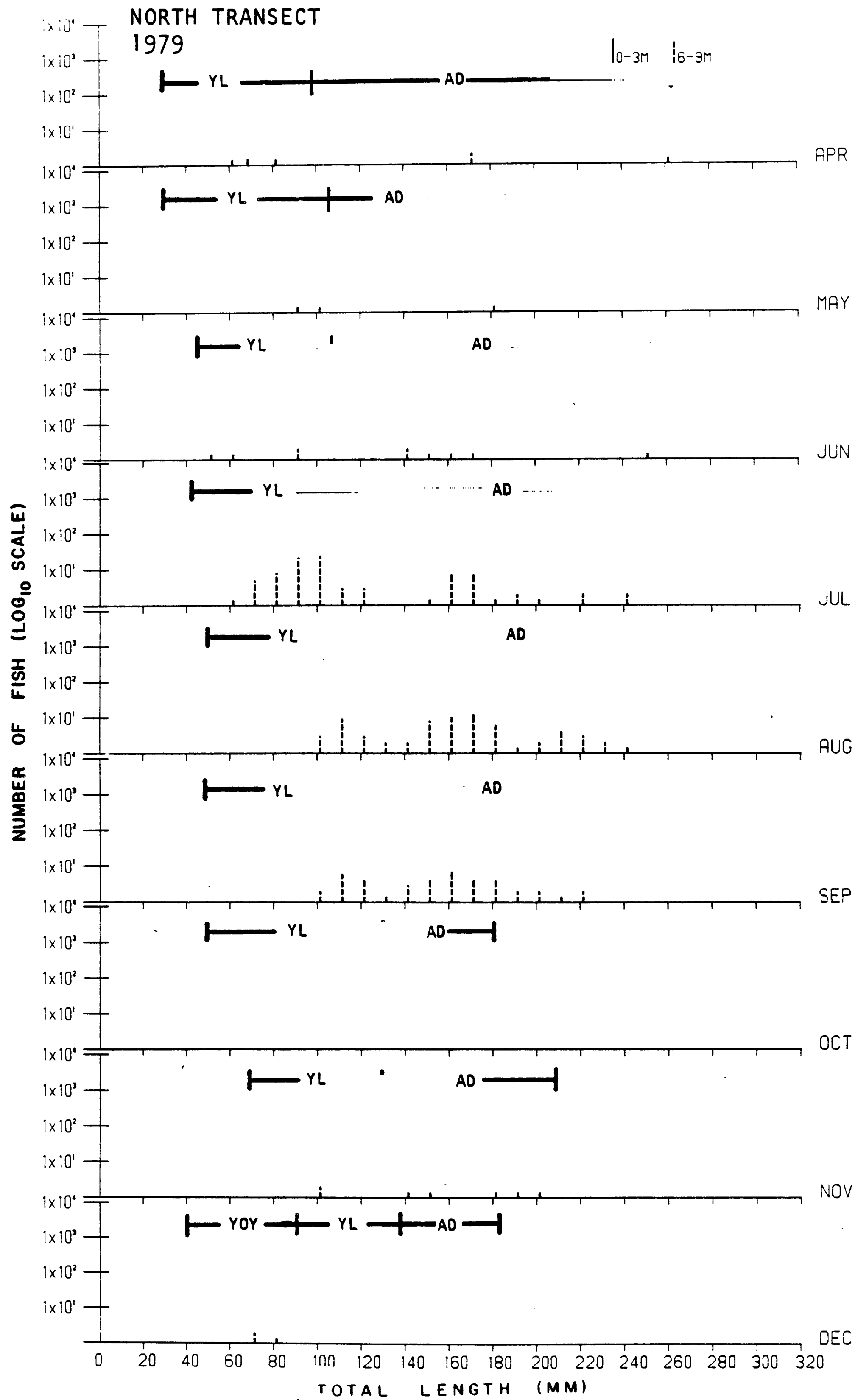

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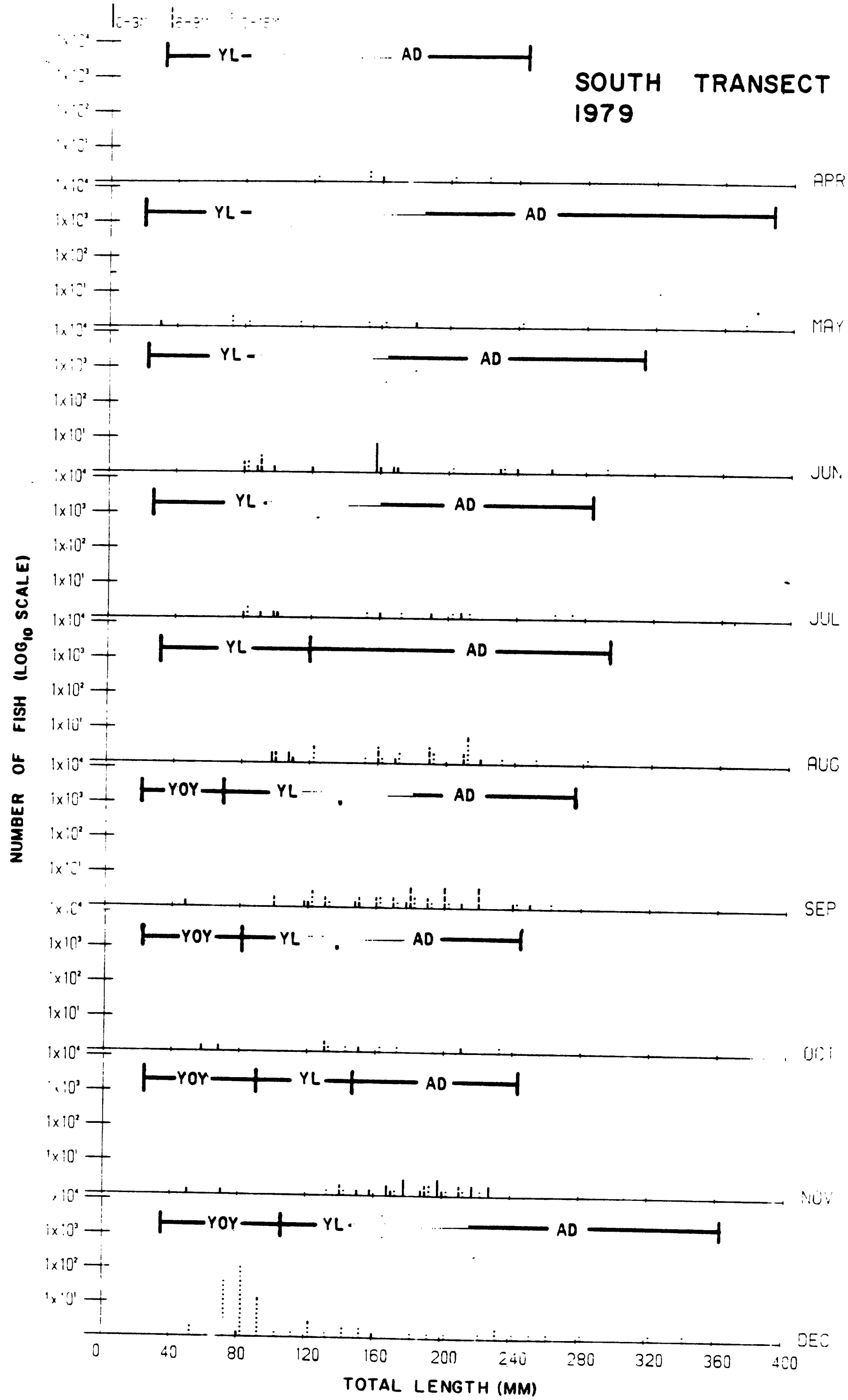

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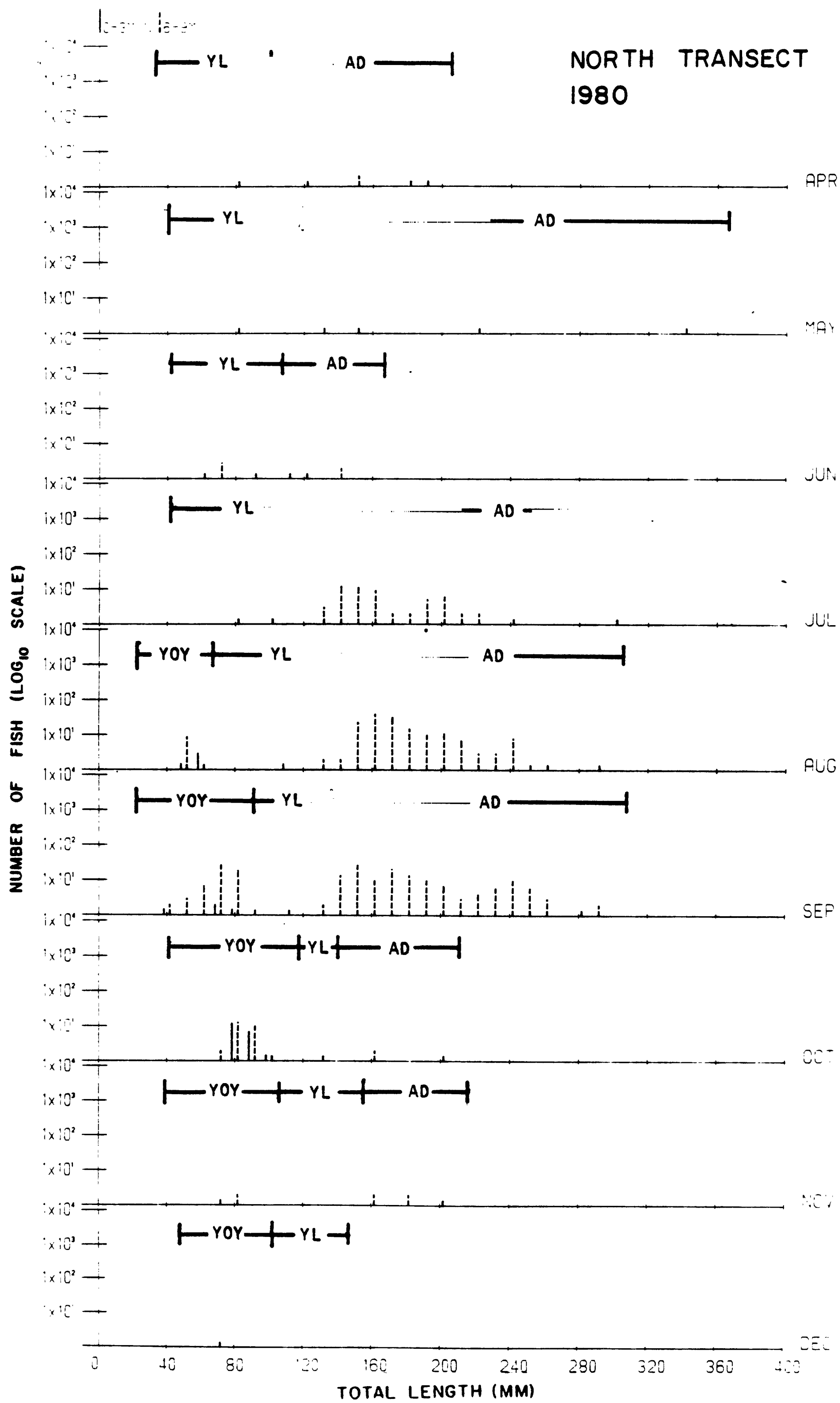

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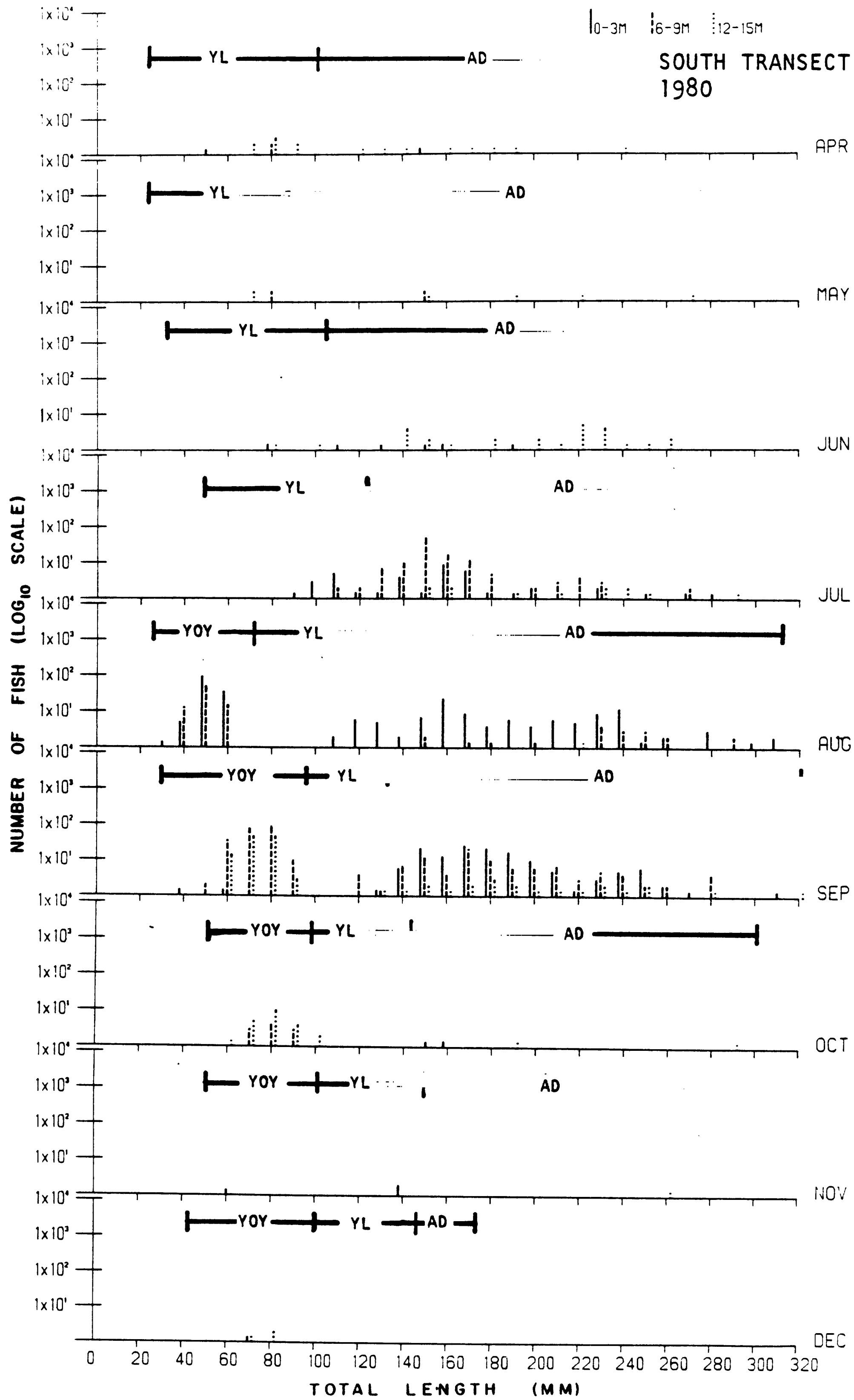


Fig. 79. Continued.

was caught in September 1979 again illustrating a possible detrimental effect upon perch reproductive success brought about by the upwelling which occurred in July of that year.

October, November and December--In general YOY perch were caught less frequently after September and fish growth slowed down or was arrested. Perch began moving to deeper water for winter. However, the number of YOY caught in December rebounded in 3 of the 4 yr of sampling (the exception was 1980). Most remarkable in this regard was the 1979 catch. Only five YOY were caught from April through November 1979, then 178 fish were caught in December. These fish may have migrated to our sampling area from a different part of the lake which was not affected by the upwelling we observed in July 1979. In December, YOY perch measured between about 35 and 104 mm.

Yearlings--

Near the J. H. Campbell Plant, yearling perch between 45 and 94 mm were caught in April. This was the same length range as YOY perch caught in December, so it is evident that little if any growth occurred during winter. Other investigators, working at northern and southern ends of Lake Michigan, have reported roughly similar sizes for yellow perch at the end of one growing season (Toth 1959; Jude et al. 1979b).

Compared with other life stages, yearling perch were numerically of least importance during each sampling season except 1978. Relatively low catches of yearlings were probably due to high mortality of YOY during their first winter of life and to yearlings spending a relatively greater proportion of their time in deep water, out of the range of our sampling gear. Yearling perch generally did not move into sampling depths (1-15 m) until July and they retreated to deeper water after September. They were therefore susceptible to sampling gear for only about 3 mo of the year.

A weak year class of YOY (such as that observed in 1979) results in an impoverished class of yearlings the following year (seen in 1980). Yearlings, following the strong 1977 YOY population, however, were prominent in 1978 samples. From these data it is reasonable to assume that yearling perch will be important in 1981 field collections since YOY produced in 1980 were relatively numerous.

<u>Seasonal distribution</u>--

April, May and June--Few yearlings were collected in April, May or June during our 4-yr study (Fig. 79). It appears therefore that yearlings lag behind adults in their movement toward shallower water after wintering at greater depths.

July, August and September--Increased numbers of yearlings, over early spring levels, were observed in July, August and September catches in all years except 1979. Fish were in length intervals from 40 to 160 mm, although most were between 70 and 120 mm. Yearling perch generally occupied water less than or equal to 9 m from July through September.

Largest numerical catches of yearlings for any given year came in July, August and September 1978 when 110, 117 and 131 fish were caught respectively. Concentration of yearling perch in 1978 shifted from the north plant transect in July to the south reference transect in August and September. During July 96% of the yearlings collected was collected at north transect stations. However, south transect stations accounted for 76% of the yearling catch in August and 77% in September. These data may suggest that perch actively seek warmer temperatures in their environment. During July, the warmest inshore water occurred at the north transect, while in August, temperatures were relatively equal between the two transects. In September, south transect water was slightly warmer than at the north transect (Fig. 22).

October, November and December--Presence of yearling perch in sampling areas diminished after September of all years. No yearlings were caught October through December 1977, and catches were negligible for this time period during other years (Fig. 79). It appears that yearlings precede adults in their fall migration to deeper water. Size range of yearling yellow perch in December was between 105 and 154 mm. Yearling perch reaching or exceeding 150 mm were somewhat exceptional in our samples, but were more frequently collected by other investigators in different parts of Lake Michigan. Brazo et al. (1975) reported that yearling perch from Lake Michigan near Ludington had an average standard length of about 160 mm at the end of their second year of growth; Jude et al. (1979b) documented that yearling perch caught during October and November, in Lake Michigan near the D. C. Cook Nuclear Power Plant, had a modal size of 150-160 mm.

Adults--

Adults dominated yellow perch catches during all study years. This is reasonable since adults were present in our sampling area during a relatively greater proportion of the year compared with YOY or yearlings and, in addition, our adult classification is comprised of several year classes (any fish beyond yearling). Adult perch caught ranged between 115 and 324 mm. According to age-length data presented by Brazo et al. (1975), Lake Michigan (Ludington) fish measuring 313 mm are 7-yr old. Thus, our samples at least included adult yellow perch from 2- to 7-yr old. Lowest numbers of adults were caught in 1979 which we attributed to an upwelling and overall low temperatures (Fig. 22).

Seasonal distribution--

April and May--Adult perch overwinter at depths beyond our deepest sampling station (15 m), but during April and May a few perch began moving to shallower water. Male perch (many with well developed gonads) are generally the first to come inshore where they congregate and await the arrival of females (Scott and Crossman 1973). Apparently fish are fully occupied by prespawning behavior during this time and generally do not feed (J. Dorr III, personal communication, Great Lakes Res. Div., Univ. of Mich., Ann Arbor, Mich.). Most fish caught were in water greater than or equal to 6 m. Perch concentrate inshore toward the end of May at which time spawning may commence if temperatures are favorable.

June--Perch were collected from all sampling depths in June, but were most abundant at 12- and 15-m stations in 1977 and 1980. In the vicinity of the Campbell Plant, perch spawning has been most prevalent during early to mid-June 1977-1980. Scott and Crossman (1973) give 8.9-12.2 C as predominant perch spawning temperatures; temperatures within this range were recorded during June each sampling year (Fig. 22). Male and female perch that were sexually spent were first seen in June, but some fish were found with well developed gonads indicating that spawning was not yet complete (Fig. 80).

When possible, perch prefer to spawn over gravel, rocks or even somewhat obscure crevices in bottom substrate (J. Dorr III, personal communication, Great Lakes Res. Div., Univ. of Mich., Ann Arbor, Mich.). Egg deposition in such locations may help stabilize eggs so that they remain in a favorable environment with fairly stable temperatures until eggs hatch (usually after about 10 days) rather than drifting randomly because of currents and wave action. Gravel or rocky substrates may also serve as underwater landmarks where fish may gather in concentrations favorable for spawning. Obviously riprap deposited over the Campbell Plant's offshore discharge and intake structures could serve the purpose described. To date, however, adult perch have not been documented as concentrating at the north transect (near the riprap) when compared with the south reference transect during May, June or July. Dredging and construction activities during 1977-1980 probably discouraged congregating perch, but it is likely that perch will be found in greater densities at the north transect in 1981. At the Palisades Nuclear Power Plant, perch were caught in greater abundances at the plant (riprap) station than at the reference (sand) station (WAPORA 1979).

July--Compared with June, perch in July were more abundant in water less than or equal to 9 m. Perch with spent gonads were collected in July of all 4 yr indicating that limited spawning activity continued beyond the period of intense spawning in June (Fig. 80). More perch were collected in beach zones during July than in previous months as fish apparently sought warmer water temperatures and food.

August--From 1977 to 1979, catch of adult perch was higher in August than in any other month. In 1980 the August catch was second only to that of September. The relatively larger catches of yellow perch in August probably relate to water temperature. Preferred temperature for yellow perch is approximately 20 C (Scott and Crossman 1973); from 1977 through 1979, water temperatures at any given sampling depth were more consistently near 20 C during August than during any other month. In August 1977, most perch were caught (all gear) in water less than or equal to 3 m where the mean temperature was 19.8 C. In 1978, adults concentrated from 6 to 9 m where mean temperatures were 20.1 C (north transect) and 19.5 C (south transect). Water in the beach zone was 15.1 C when field work was performed in 1979 and most adults may have been in deeper water. In 1980 mean temperatures of 18.3 C were recorded in water less than or equal to 3 m and many adults were collected. However, more perch were caught in water from 6- to 9-m deep during August 1980 when water temperatures were only 14.9-15.5 C.

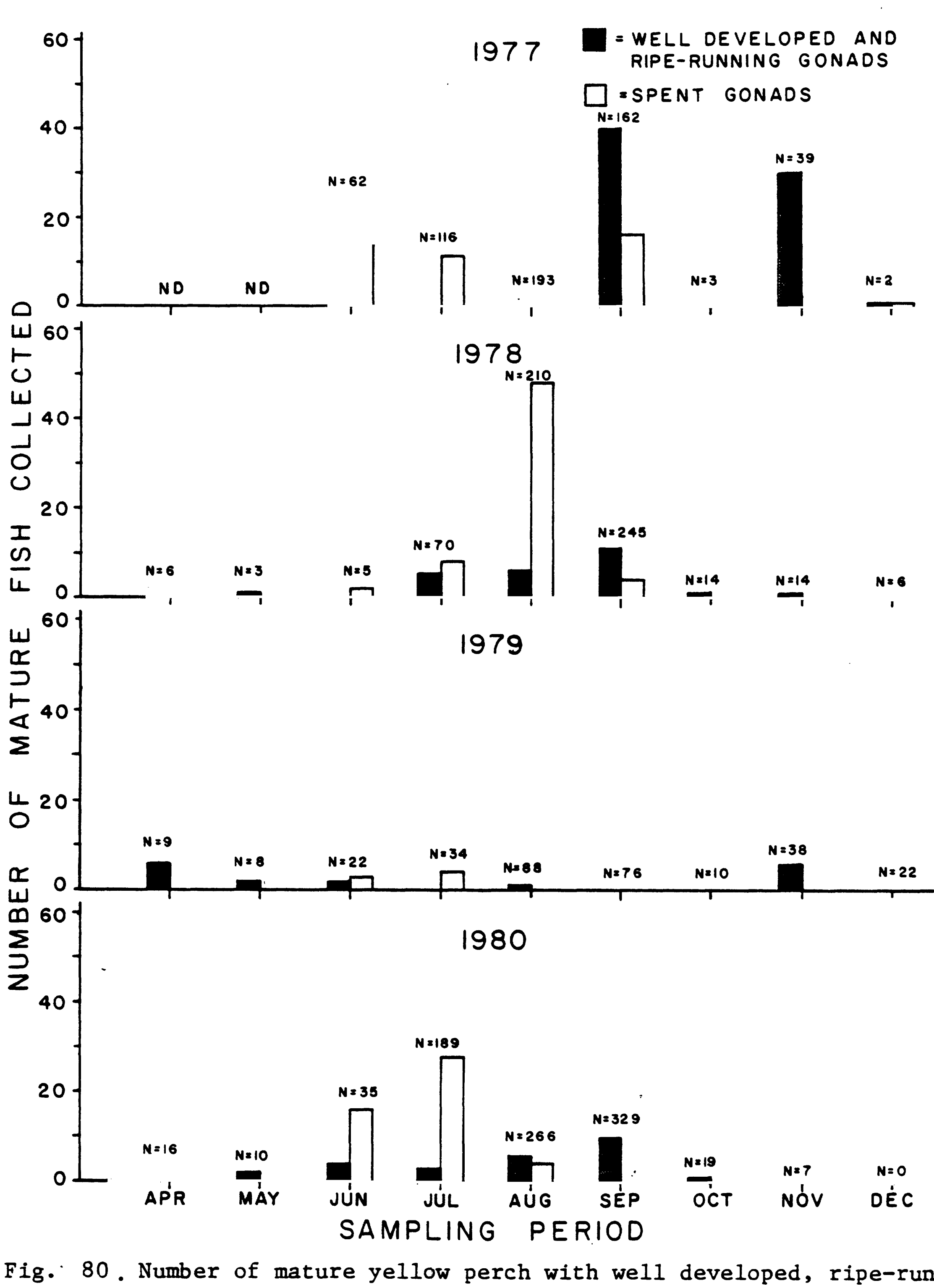


Fig. 80. Number of mature yellow perch with well developed, ripe-running and spent gonads collected monthly during June-December 1977 and April-December 1978-1980 near the J. H. Campbell Plant, eastern Lake Michigan. N = total number of mature yellow perch caught per month.

September--Adult perch were prominent in our sampling area in September of all years. Water temperature dropped rather drastically between August and September 1977 (Fig. 22), yet relatively large numbers of adults were captured in September. During 1978-1980 September temperatures were not greatly different from those in August, and perch were caught primarily at depths less than or equal to 9 m.

October, November and December--Catches of adult perch dropped precipitously after September. In general, falling temperatures and decreasing catches were observed from October through December. Perch appeared to move to deeper water during fall and remained outside our sampling depths through winter.

Plant Effects--

From 1977 through 1980, yellow perch (larvae-adults) were sampled in varying numbers at both north (plant) and south (reference) transects. No consistent yearly catch pattern was evident for either transect. Results from the Wilcoxon signed ranks test indicated that greater densities of perch larvae were present at north transect stations than at south transect stations in 1979. A relatively high mean larval perch density (60/1000 m^3) at beach-3 m at the north transect in June accounted for the difference between transects. Considering all 4 yr however, overall densities of perch larvae were not significantly different according to the Wilcoxon test. Spawning perch are attracted to rocky areas such as that present near the Campbell intake and discharge structures, yet adult perch were not observed to concentrate in this area during spawning season, probably due to dredging and construction activities. However, perch were found near the riprap in relatively large numbers at other times of the year, most notably during 1979. Bottom gill net data for juvenile and adult yellow perch showed a higher abundance of perch at the plant transect than at the reference transect during 1979 due to an unusually low catch at station C (6 m, south) during that year (Fig. 81, Tables 46-48). In 1979, for trawl data, significantly greater numbers of yellow perch were caught at the north transect than at the south transect, due mostly to yearlings and adults which were captured in August and September trawls (Fig. 82, Tables 49 and 50). It was felt that these fish were feeding on benthic organisms which were dislodged and suspended in the water column by the dredging activity (Jude et al. 1980). Relatively large YOY catches at the south transect in August and September contributed to a difference between catches at the two transects in 1980 (Fig. 82). However, this difference was felt to be due to spurious catches from the south transect.

Since construction activities at intake and discharge structures were completed during early 1980, it is likely that perch will be attracted to the riprap area to spawn in 1981. If this occurs, perch spawning effort could be influenced by plant operation. Perch spawning largely takes place at depths from 5 to 9 m, but may well extend to deeper water in the Campbell riprap area due to the presence of suitable rock substrate. Campbell intake structures are situated at about 11 m. Eggs deposited near intake structures would probably not be affected by the low intake currents observed by SCUBA divers

YELLOW PERCH

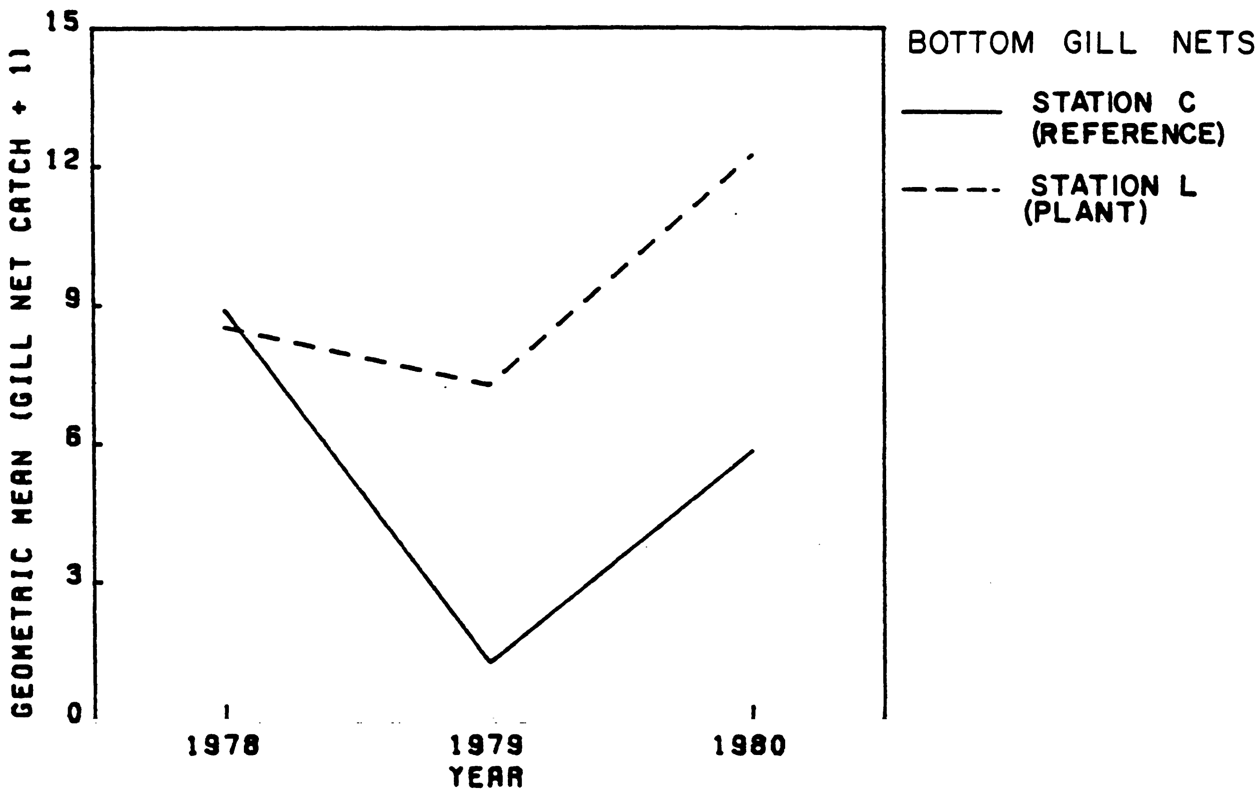


Fig. 31. Geometric mean number plus one of yellow perch caught in bottom gill nets at stations C (6 m, south) and L (6 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1978 through 1980. Graph illustrates YEAR X STATION interaction.

since perch would anchor their gelatinous rope-like egg masses in rocks. Additionally perch larvae are fast growing and good swimmers at early ages. Thus perch larvae at about 7 mm would be able to avoid both entrainment and impingement at offshore intake screens. However, newly hatched perch or those retaining their yolk sacs are inactive and passive so perch hatched near intake structures may be subject to entrainment loss during their first few days of life. Additionally, it is possible that larger larvae will be entrained if they are attracted to intake structures to seek cover.

Table 46. Analysis of variance summary for yellow perch caught in bottom gill nets at stations C (6 m, south) and L (6 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1977 through 1980. Data for July through September were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	3	0.8544	15.0814	<0.0001**
Month	2	0.4845	8.5522	0.0007**
Station	1	0.2996	5.2877	0.0259
Time	1	0.3118	5.5043	0.0231
Y x M	6	0.4560	8.0486	<0.0001**
Y x S	3	1.2978	22.9065	<0.0001**
M x S	2	0.3587	6.3317	0.0036*
Y x T	3	0.1843	3.2531	0.0296
M x T	2	0.3534	6.2385	0.0039*
S x T	1	0.1431	2.5252	0.1186
Y x M x S	6	0.2565	4.5271	0.0010*
Y x M x T	6	0.2603	4.5944	0.0009**
Y x S x T	3	0.0600	1.0586	0.3755
M x S x T	2	0.1342	2.3688	0.1044
Y x M x S x T	6	0.2852	5.0345	0.0004**
Within cell error	48	0.0567		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

Table 47. Analysis of variance summary for yellow perch caught in bottom gill nets at stations C (6 m, south) and L (6 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1978 through 1980. Data for August and September were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	2	1.1007	14.2074	0.0001**
Month	1	0.1657	2.1391	0.1566
Station	1	1.5171	19.5817	0.0002**
Time	1	0.0816	1.0536	0.3149
Y x M	2	0.0747	0.9636	0.3958
Y x S	2	0.6156	7.9461	0.0022*
M x S	1	0.2640	3.4077	0.0773
Y x T	2	0.1537	1.9839	0.1594
M x T	1	0.0017	0.0224	0.8824
S x T	1	0.0262	0.3384	0.5662
Y x M x S	2	0.1434	1.8516	0.1787
Y x M x T	2	0.0342	0.4412	0.6484
Y x S x T	2	0.1194	1.5418	0.2345
M x S x T	1	0.2107	2.7200	0.1121
Y x M x S x T	2	0.2351	3.0345	0.0668
Within cell error	24	0.0775		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

Table 48. Analysis of variance summary for yellow perch caught in bottom gill nets at stations C (6 m, south), D (9 m, south), L (6 m, north) and N (9 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1980. Data for August and September were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Month	2	0.1721	2.6400	0.0920
Area	1	0.2102	3.2238	0.0852
Depth	1	3.2142	49.3060	<0.0001**
Time	1	0.8908	13.6650	0.0011*
M x A	2	0.5626	8.6302	0.0015*
M x D	2	0.1195	1.8338	0.1815
A x D	1	0.0021	0.0328	0.8578
M x T	2	0.0554	0.8498	0.4400
A x T	1	0.3643	5.5885	0.0265
D x T	1	0.1223	1.8763	0.1834
M x A x D	2	0.0449	0.6885	0.5120
M x A x T	2	0.0998	1.5316	0.2366
M x D x T	2	0.1580	2.4243	0.1099
A x D x T	1	0.0018	0.0283	0.8678
M x A x D x T	2	0.7732	11.8615	0.0003**
Within cell error	24	0.0652		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

Table 49. Analysis of variance summary for yellow perch caught in trawls at stations C (6 m, south) and L (6 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1977 through 1980. Data for July through September were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	3	0.6112	17.1218	<0.0001**
Month	2	1.2587	35.2626	<0.0001**
Station	1	0.2269	6.3579	0.0151
Time	1	0.3179	8.9070	0.0045*
Y x M	6	1.3690	38.3528	<0.0001**
Y x S	3	0.4011	11.2374	<0.0001**
M x S	2	0.2239	6.2724	0.0038*
Y x T	3	0.4833	13.5393	<0.0001**
M x T	2	0.2604	7.2957	0.0017*
S x T	1	0.0081	0.2260	0.6367
Y x M x S	6	0.5006	14.0234	<0.0001**
Y x M x T	6	0.2892	8.1030	<0.0001**
Y x S x T	3	0.0649	1.8169	0.1567
M x S x T	2	0.1672	4.6831	0.0139
Y x M x S x T	6	0.3279	9.1869	<0.0001**
Within cell error	48	0.0357		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

Table 50. Analysis of variance summary for yellow perch caught in trawls at stations C (6 m, south), D (9 m, south), L (6 m, north) and N (9 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1978 through 1980. Data for July through September were analyzed.

Source of variation	df	Mean square	F-statistic	Attained significance level
Year	2	0.7058	18.2942	<0.0001**
Month	2	1.2840	33.2792	<0.0001**
Area	1	0.3126	8.1015	0.0058*
Depth	1	0.2623	6.7988	0.0111
Time	1	0.0266	0.6890	0.4093
Y x M	4	2.0707	53.6723	<0.0001**
Y x A	2	1.1452	29.6831	<0.0001**
M x A	2	0.2370	6.1416	0.0034*
Y x D	2	0.5090	13.1926	<0.0001**
M x D	2	0.0647	1.6760	0.1943
A x D	1	0.1152	2.9847	0.0883
Y x T	2	0.3456	8.9568	0.0003**
M x T	2	0.0375	0.9729	0.3829
A x T	1	0.0135	0.3488	0.5566
D x T	1	0.5532	14.3384	0.0003**
Y x M x A	4	0.1778	4.6074	0.0023*
Y x M x D	4	1.0807	28.0113	<0.0001**
Y x A x D	2	0.0690	1.7877	0.1747
M x A x D	2	0.1190	3.0849	0.0518
Y x M x T	4	0.0714	1.8508	0.1285
Y x A x T	2	0.0553	1.4324	0.2455
M x A x T	2	0.0685	1.7764	0.1766
Y x D x T	2	0.4713	12.2148	<0.0001**
M x D x T	2	0.4967	12.8737	<0.0001**
A x D x T	1	0.0016	0.0419	0.8384
Y x M x A x D	4	0.9327	24.1762	<0.0001**
Y x M x A x T	4	0.3546	9.1902	<0.0001**
Y x M x D x T	4	0.4625	11.9875	<0.0001**
Y x A x D x T	2	0.1965	5.0922	0.0085*
M x A x D x T	2	0.2970	7.6992	0.0009**
Y x M x A x D x T	4	0.5201	13.4819	<0.0001**
Within cell error	72	0.0386		

** Highly significant ($P < 0.001$).
* Significant ($P < 0.01$).

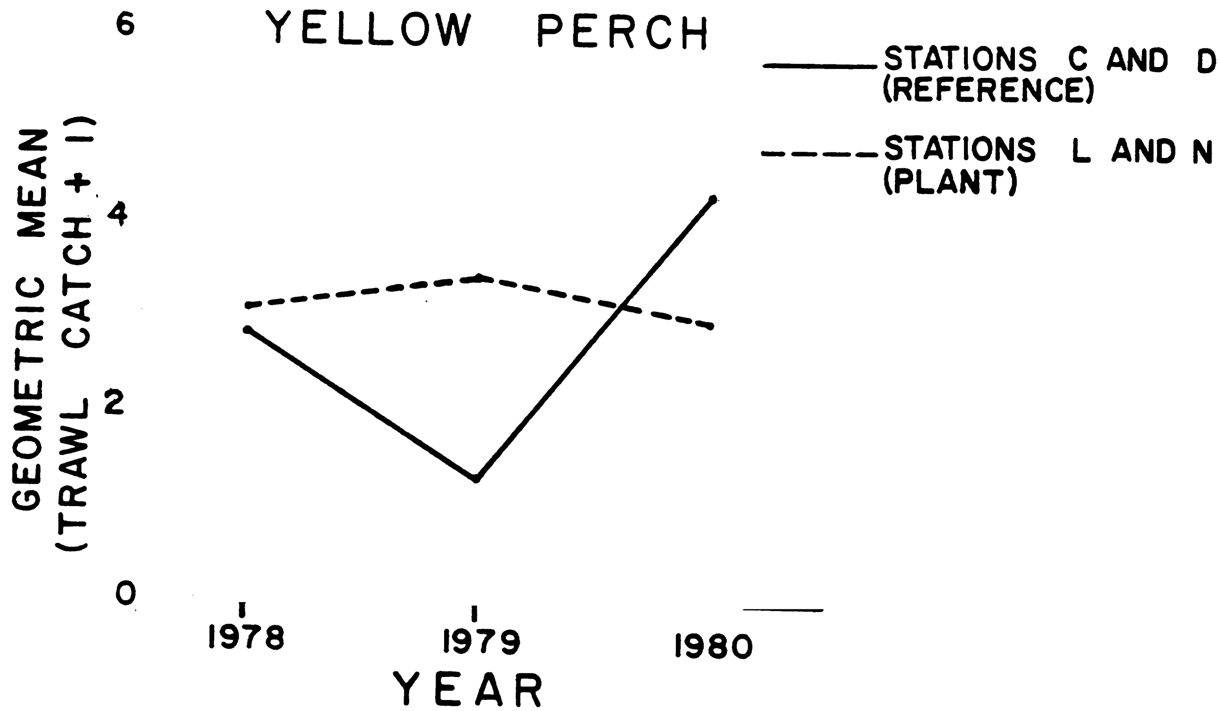


Fig. 82. Geometric mean number plus one of yellow perch caught in trawls at stations C (6 m, south), D (9 m, south), L (6 m, north) and N (9 m, north) near the J. H. Campbell Plant, eastern Lake Michigan, 1978 through 1980. Graph illustrates the YEAR x AREA interaction.

LESS ABUNDANT SPECIES

Lake Trout

Introduction--

Lake trout are naturally occurring and widely distributed throughout northern North America. Southern Lake Michigan marks the southern-most extension of the species' natural range, although they have been widely introduced (Scott and Crossman 1973). Lake trout are characteristically found in the cooler, hypolimnetic region of cold-water lakes. In the Great Lakes this species is usually most abundant at depths between 30 and 91 m at or near the bottom, but may occur in open water (Eschmeyer 1957). Midsummer movement of lake trout into nearshore areas of southeastern Lake Michigan has been observed when upwelling conditions prevail (Jude et al. 1979a, 1980). Spawning occurs in the fall. Historically, mature fish migrated to their native reefs, typically rocky, current-swept shoals at depths of up to 30.5 m (Eschmeyer 1957).

Attempts to reestablish lake trout in Lake Michigan following their near extinction due to combined effects of overfishing and lamprey predation during the 1930s and 1940s, resulted in the planting of yearlings in shallow, nearshore areas. Consequently, fall spawners of late (1969 to present) are believed to be returning to spawning areas that are shallower and possibly less suitable for natural reproduction than historical spawning reefs (Rybicki and Keller 1978; Dorr et al. 1981).

During 1980, 513 lake trout were collected in Lake Michigan near the J. H. Campbell Plant including 442 adults (330-950 mm), 10 juveniles (110-280 mm) and 61 larvae and fry (22-62 mm). This represents a two-fold increase over previous annual catches of 201, 258 and 222 in 1977, 1978 and 1979 respectively (Jude et al. 1978, 1979a, 1980).

Larvae--

Collection of 61 lake trout fry in our study area during spring and summer 1980 documents successful reproduction in southeastern Lake Michigan for the first time since the species was reintroduced from hatchery stocks in 1965 (Jude et al. 1981b). Presumably hatched in late February-March 1980, fry (26-27 mm) (some were sac fry) were first collected in April at station O (12 m, north) (one) and W (15 m, north) (one) in the immediate vicinity of the riprap-covered intake pipe (Fig. 83). In May greater numbers of fry were collected (47). Their occurrence at both north and south transects, in 3 to 15 m of water indicates dispersal of fry up to 5 km away from the presumed site of incubation (Jude et al. 1981b). The greatest number of fry were captured at station N (9 m, north) (19) and station E (12 m, south) (17) in both trawls and larval sled tows. Four fry (37-43 mm) were collected in June, all at the south transect at 3-, 12- and 15-m stations. Mean July water temperature at 12 and 15 m, which exceeded 15 C (Fig. 22), was sufficiently high to force fry in the vicinity to seek deeper colder water. Lower offshore water temperatures in August (7.0-7.5 C) permitted reentry of fry into our study area as three (55-62 mm) were captured at station F (15 m, south).

Juveniles--

Juvenile lake trout (44 fish, 110-276 mm) occurred infrequently within our study area during all years (1977-1980). Most (40) were collected in trawls and a few (4) were gill netted. Seventy-three percent were captured at depths of 9 m or greater. A size-depth relationship has been evident for lake trout in southeastern Lake Michigan with average length of fish decreasing with depth (Great Lakes Fishery Laboratory 1972).

The preferred temperature for yearling lake trout (11.7 C) is thought to be about 2 C warmer than the temperature at which lake trout are most often caught in thermally stratified lakes (McCauley and Tait 1970). Young lake trout were present inshore (1.5-3 m) during spring months (May and June, Fig. 84) in 1980 and 1979. Temperatures at the time of capture were 12.7 C at station A (1.5 m, south) in May 1979 and 14.5 C at station B (3 m, south) in June 1980. Juveniles were also captured nearshore at station L (6 m, north) in July 1978 and 1979 (Fig. 84), when water temperature data (Fig. 22)

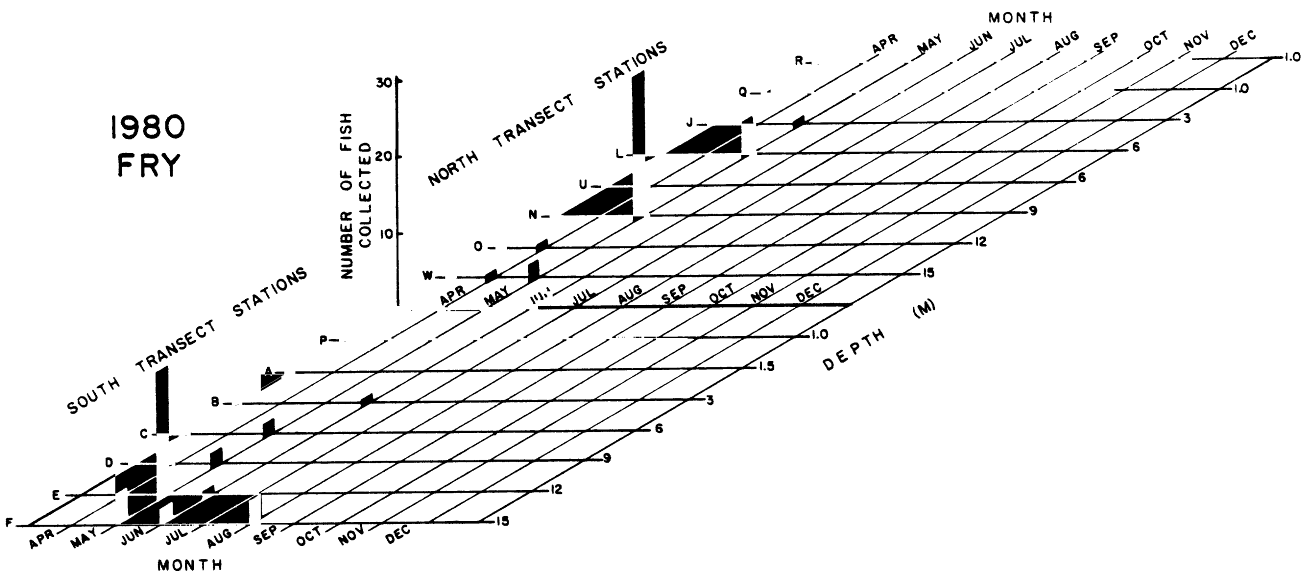


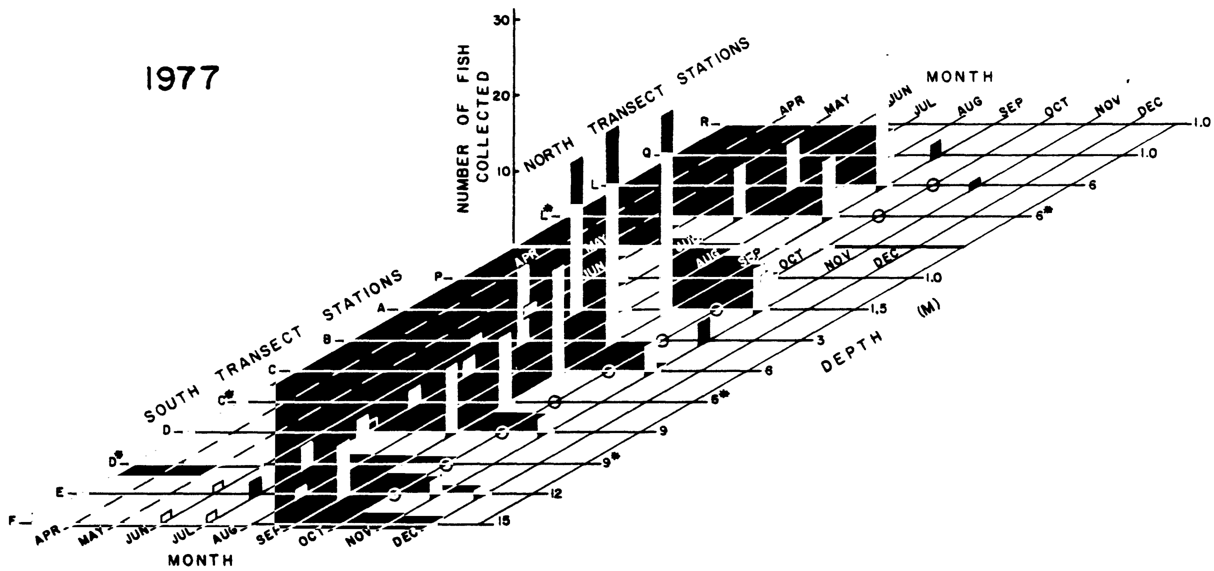
Fig. 83. Numbers of lake trout fry collected in trawls and larval sled tows for each month and station during 1980, near the J. H. Campbell Plant, eastern Lake Michigan.

indicated upwellings existed. Unlike adults, young lake trout remain in deeper water during the fall and are therefore not as susceptible to capture in our study area during that time.

Adults--

Adults comprised 91% of all lake trout collected over the 4-yr study period. Eighty-seven percent of the 1167 adults collected were captured at night, with annual percentages ranging from 80 to 90%. Jude et al. (1979b) reported night catches of lake trout in southeastern Lake Michigan near the D. C. Cook Nuclear Plant ranging from 83 to 91% (1973-1974). The authors attributed these high percentages to fall spawning activity which is known to be a nocturnal event for this species (Scott and Crossman 1973). This explanation seems plausible here since the majority of all adult lake trout captured in our study area were collected during the spawning season, from September to November.

Gill nets were responsible for catching over 97% of adult lake trout in each of the 4 yr studied. At stations where both surface and bottom gill nets were set [stations C (6 m, south); L (6 m, north); U (6 m, north) set only in 1980; and D (9 m, south) set only in 1977], 67 to 71% of the catch occurred in bottom gill nets. Two adult lake trout were trawled in 1980, one at station E (12 m, south) in April and one at station B (3 m, south) in October. Three were collected in trawls during 1979, none in 1978 and one in 1977. Few lake trout were collected in seine hauls: 1980 (0); 1979 (0); 1978 (10); 1977 (3).



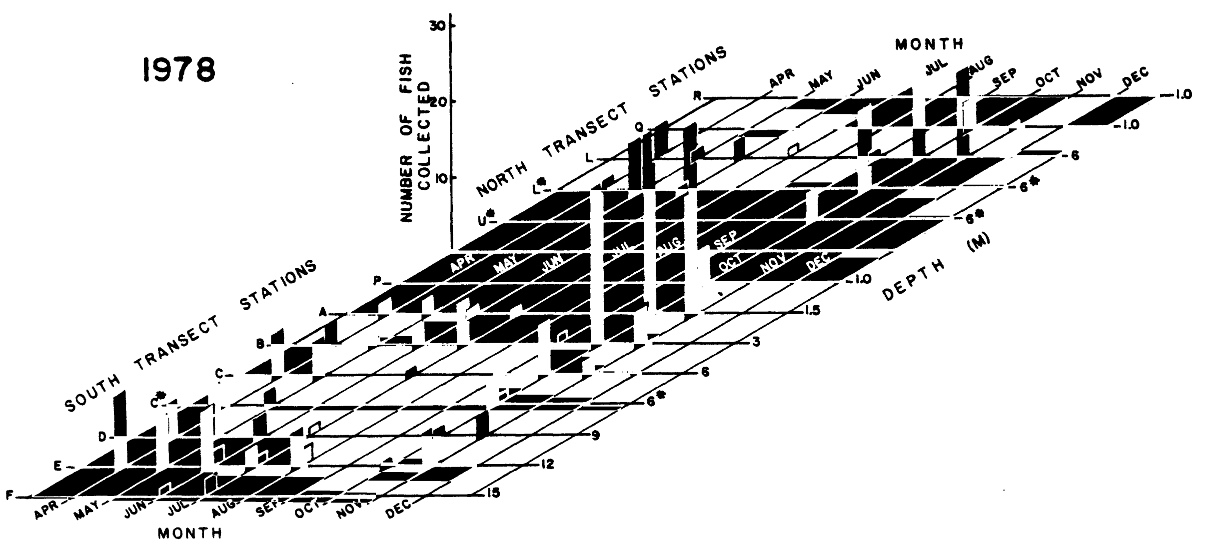
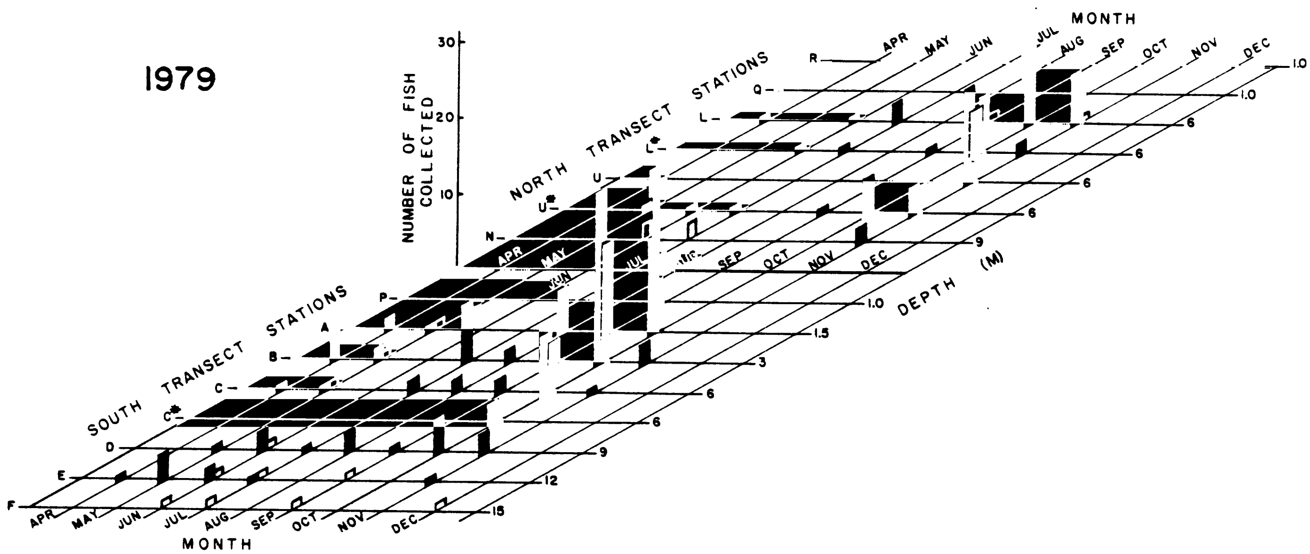


Fig. 84. Numbers of adult and juvenile lake trout collected in all gear for each month, station and year near the J. H. Campbell Plant, eastern Lake Michigan, 1977 through 1980. □ = juveniles, ■ = adults, ○ = standard schedule gillnetting not performed, ✱ = surface gill net, dashed line indicates no sampling performed. Refer to METHODS (Tables 1 and 2) for standard sampling schedule.



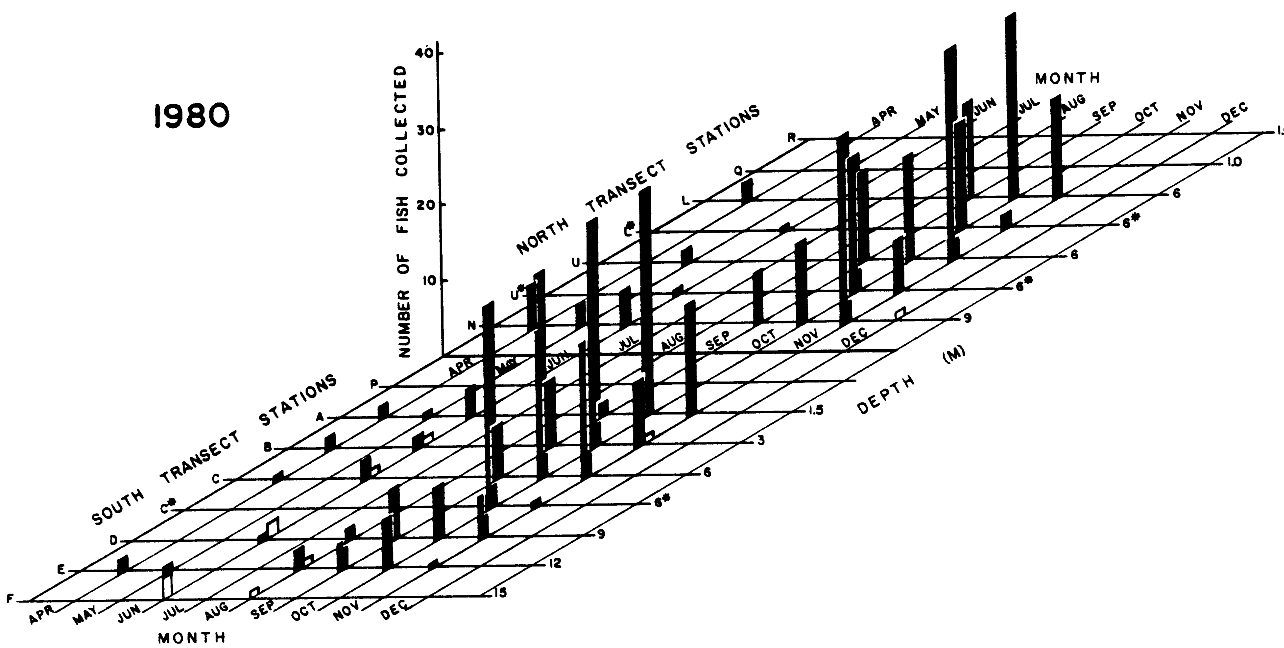


Fig. 84. Continued.

Temperature is a major factor influencing the distribution of lake trout. Spigarelli (1975) determined the preferred temperature for adults of this species in the nearshore area of Lake Michigan in the vicinity of a power plant discharge to be 11.8 C. In 1980 over 95% of the lake trout caught in our study area were in water 15 C or less (Appendix 2). Comparable temperature-catch relationships were observed from 1977 through 1979 (Jude et al. 1978, 1979a, 1980).

During spring of all study years, monthly mean water temperatures at 6- and 9-m gill net stations ranged from 2.4 to 5.9 C in April, 6.6 to 11.5 C in May and 6.3 to 14.0 C in June (Fig. 22). Temperatures at 1.5- and 3-m gill net stations for the same period were somewhat higher, yet within a range that lake trout would be likely to occur, 6.8 to 9.9 in April; 8.3 to 13.8 in May and 9.9 to 17.3 C in June. Few adult lake trout however, were captured during these months (Fig. 84). Largest catches occurred in 1978 when 82 fish were collected, while abundances in 1980 and 1979 were 41 and 24 fish respectively.

Analysis of stomach contents indicated lake trout were actively feeding in the study area from April through June, as 80% of those examined contained food. Rainbow smelt were present in 42% of the stomachs containing food in April; this percentage dropped to 6% in June. Alewives increased in abundance as a food item from 18 to 62% for the same period. The relatively low spring catch of lake trout in 1979 may have been influenced by the relatively low abundance of forage fish in the study area. Numbers of rainbow smelt (305) and alewives (0) collected in April 1979 were low compared to a greater abundance in 1978 (1093 rainbow smelt, 21 alewives) and 1980 (2089 rainbow smelt, 152 alewives) (Table 10). Furthermore, the offshore movement of lake trout into deeper water, necessitated in late spring by rising nearshore water temperatures, may have been initiated earlier in 1979 than in 1978 or 1980 because of the rapid warming of inshore water from April to May (Fig. 22).

Lake trout were present inshore during the summer (July and August) when suitable temperatures were available. Cold-water upwellings in July 1977, 1978 and 1979 permitted nearshore residence of lake trout. Rising temperatures from July to August all but eliminated lake trout from the area in 1978 (five fish captured) and 1977 (one fish captured), while large catches in 1.5- and 3-m gill nets attested to the availability of suitable temperatures in 1979. Mean July water temperatures of 19.9 and 21.0 C at 6- and 9-m stations excluded lake trout from our study area in 1980 (Fig. 22, Fig. 84). A sparse August catch of three fish reflects limited inshore movement, as bottom temperature dropped within a more tolerable range for the species.

The fall spawning migration of lake trout into shallow, nearshore areas produced seasonal high abundances during all study years. The combined September, October and November catch of 836 represented 77% of all adults collected. Fifty-seven percent of these fish were found to be in spawning or near spawning condition as indicated by gonad condition data. Examination of stomach contents suggests that most of these fish were not feeding in the area. Greatest catches occurred at 1.5-, 3- and 6-m stations. Shallow,

inshore areas have been reported to attract large concentrations of spawning lake trout presumably as a result of stocking yearlings in such areas to which planted stocks "home" as adults (Rybicki and Keller 1978).

During 1980, 387 adult lake trout were collected from September through November. Notably fewer fish were captured during this period in 1979 (146) and 1978 (146). The aggregation of mature fish over nearshore spawning areas appeared to begin in September, peaked in October and declined in November when spent individuals began to appear (Fig. 85). The large number of lake trout collected in September 1977 suggests that the cumulative fall catch for this year may have equalled that of 1980. However, gill net sampling necessary to confirm this contention was not performed in October 1977.

Successful lake trout spawning and reproduction in our study area during fall 1979 was evidenced by the occurrence of lake trout fry in spring and summer samples the following year (Fig. 83). Stomach analysis of 10 round whitefish collected in fall 1980 disclosed the occurrence of lake trout eggs, ranging in abundance from 1 to 50 eggs per individual. One of these fish was captured in October. The remaining nine were caught in November at both north and south transects, suggesting that lake trout spawning had occurred in the vicinity of our study area during 1980. There have been other reports of lake trout spawning in nearshore areas of southeastern Lake Michigan. An estimated 100,000 lake trout eggs were observed along the Lake Michigan shoreline in the vicinity of the D. C. Cook Plant in November 1975 (Jude et al. 1979a). Occurrence of these eggs followed an intense storm that passed through the area the day before.

Examination of lake trout for lamprey scars revealed an overall decline in the frequency of attacks from 1977 through 1980. Twenty-three percent of 428 fish examined in 1980 had lamprey scars (Table 51). This value along with the 24% observed in 1979 substantiated a downward trend in scar frequency from 1978 (36%) and 1977 (27%) (Jude et al. 1980, 1979a, 1978). Other authors have reported scarring rates of 25% in Indiana waters of Lake Michigan (McComish and Miller 1975) and 22% near the D. C. Cook Plant (Jude et al. 1979b). Occurrence of fresh lamprey wounds on only 2% of the lake trout examined in 1980 suggests low lamprey activity within our study area.

Plant Effects--

Several noteworthy observations on the distribution and abundance of lake trout during the 4 yr of preoperational data collection deserve special mention. Most significantly has been the unique occurrence of lake trout fry in 1980. It is believed the newly laid riprap covering the intake pipe provided a suitable environment for egg incubation during the previous winter (1979-1980). This type of substrate is similar in structure to historical spawning reefs, protecting the indiscriminately dispersed eggs from severe wave action and ice scour, which could otherwise damage unprotected eggs occurring on sand bottoms.

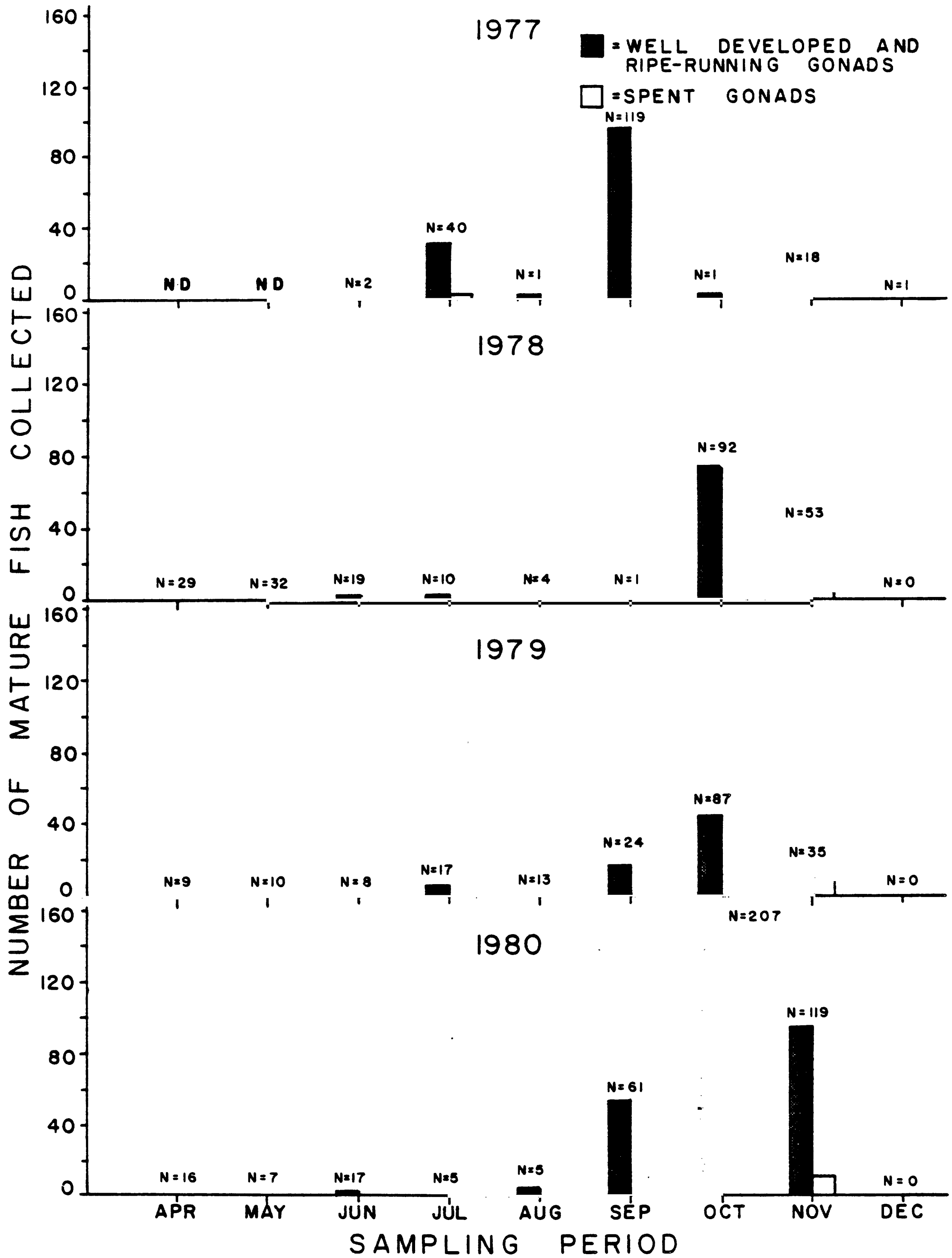


Fig. 85. Number of mature lake trout with well developed, ripe-running and spent gonads collected monthly during June-December 1977 and April-December 1978-1980 near the J. H. Campbell Plant, eastern Lake Michigan. N = total number of mature lake trout caught per month.

Table 51. Occurrence of sea lamprey scars on lake trout caught near the J. H. Campbell Plant, eastern Lake Michigan, 1980.

Length Interval (mm)	Total Number Examined	Number Scarred	Percent Scarred	No. scars per fish			
				1	2	3	4
900-949	1						
850-899	5	3	60	3			
800-849	15	8	53	4	1	3	
750-799	74	26	35	18	6	1	1
700-749	105	32	30	29	2	1	
650-699	147	25	17	22	2	1	
600-649	52	3	6	2	1		
550-599	17	1	6	1			
500-549	4						
450-499	2						
400-449							
350-399							
300-349							
250-299	1						
200-249							
150-199	1						
100-149	4						
Total	428	98	207	79	12	6	1

Differences in the fall abundance of lake trout between plant (north) and reference (south) transects were evident in 1978 and 1979 (Table 51). Consistently greater catches from September through November at north transect stations occurred while there was a high level of construction activity in the area, including dredging for the deposition of riprap. However, during the years of greatest lake trout abundance (1980 and most likely 1977), construction activity in the vicinity of the plant transect was absent and catch differences between transects were not as obvious. Temperature differences in November 1980 between stations U (6 m, north) and L (6 m, north), which lie north and south of the offshore discharge, revealed the presence of the thermal plume. These water temperature differences appear to have influenced the distribution of lake trout in the immediate vicinity (Table 52). Colder water (5 C) at station U (6 m, north) attracted greater numbers of lake trout (31) than plume-influenced station L (6 m, north) (15 fish, 9 C). An intermediate catch (19) was observed at reference station C (6 m, south) where water temperature was 5.8 C.

Table 52. Number of lake trout collected in bottom and surface gill nets set in Lake Michigan in September, October and November 1977-1980 at stations L (6 m, north) designated as north and C (6 m, south) designated as south. Day and night catches were pooled. Water temperature, in degrees Celsius, at time of capture is enclosed in parentheses. # denotes operation of 6-m offshore discharge; ## denotes operation of onshore discharge; ** denotes presence of introduced substrate such as riprap in the discharge area; ### denotes construction activity in the discharge area. ND denotes no data.

		Month			
Year	Transect	Sep	Oct	Nov	Total
1980	North (plant)	13	39	15*	67
#		(16.2)	(12.0)	(9.0)	
**	South (ref.)	7	54	19	80
		(15.2-13.0)	(10.5)	(5.8)	
	Total				147
1979	North (plant)	5	21	10	36
**		(14.0-11.7)	(13.7-13.0)	(8.5-6.9)	
###	South (ref.)	2	11	1	14
##		(14.5)	(13.5-13.0)	(7.2)	
	Total				50
1978	North (plant)	1	24	12	37
**		(13.5)	(12.9-12.0)	(9.0)	
###	South (ref.)	0	11	2	13
##		(19.8-15.6)	(12.5-11.7)	(8.5)	
	Total				50
1977	North (plant)	25	ND	1	26
##		(10.6-6.0)		(15.3)	
	South (ref.)	23	ND	4	27
		(9.0-7.3)		(10.6)	
	Total				53

* November gill net catch of lake trout at station U (6 m, north) was 31; water temperature was 5 C.

White Sucker

Introduction--

White sucker was the eighth-most abundant species taken in Lake Michigan during 1980. There were 392 individuals collected, representing 0.47% of the total catch. During the 4 yr of the study the importance of white suckers in the total catch was between 0.3 and 0.6% (Jude et al. 1978, 1979a, 1980). In 1977, 294 white suckers were collected; 319 were taken in 1978 and 413 in 1979. White suckers comprised only 0.1% of the catch in 1973-1974 in southeastern Lake Michigan near the D. C. Cook Nuclear Power Plant, Bridgman, Michigan (Jude et al. 1979b).

Larvae--

In April, adult white suckers in the study area migrate into streams to spawn. Sucker larvae were captured infrequently in the Campbell Plant vicinity because they spend at least 1 mo in streams before moving down to the lake (Geen et al. 1966). In the early years of the study, sucker larvae could not be identified to species; however, since white suckers are the most common catostomid in the study area, most sucker larvae collected were probably white suckers. During our study, only two sucker larvae were captured in Lake Michigan; one in April and one in July 1979 at depth contours of 1 and 3 m respectively. These larvae were 10.0 and 12.0 mm TL. Sucker larvae were also taken in entrainment samples at Units 1 and 2 during May 1978 and 1979, indicating spawning took place during April and early May in the Pigeon River. The larva caught in July 1979 may have been spawned during an upwelling which took place that year, although spawning in Lake Michigan is not documented for white suckers. This larva more likely originated from a late spawning in the Pigeon River.

Young-of-the-Year and Yearlings--

Growth rates of white suckers vary considerably among studies, making separation of year classes difficult. Koehler (1978) found that white sucker YOY near Ludington averaged 100 mm and yearlings averaged 225 mm. Other studies (Carlander 1969; Hubbs and Creaser 1924) found YOY no larger than 70 mm by August. Few small white suckers have been collected near the Campbell Plant. In 1977, 1978 and 1980, a few fish smaller than 74 mm (probably YOY) were captured, all in beach seines in July and August. White suckers 75-244 mm (probably yearlings) were also infrequent and scattered in catches, being captured both in seines and in bottom gill nets from the 3- to 12-m contours. At the D.C. Cook Plant all white suckers less than 144 mm were collected with beach seines, and no 145-244-mm fish were taken (Jude et al. 1979b).

YOY white suckers collected near the Campbell Plant and the Cook Plant had newly emerged from streams, as evidenced by their small size (most were 50-65 mm) and restriction to the beach zone. Scarcity of YOY and yearlings, compared with adults, suggests most young white suckers remain in streams up to 1 yr before moving downstream to Lake Michigan. Those white suckers

emerging from streams in their first year inhabit the beach zone only briefly before moving offshore out of our sampling area, or undergo considerable mortality.

Adults--

Adult white suckers were captured most effectively by bottom gill nets during the 4 yr of our study and near Ludington (Liston and Tack 1973). This was probably due to this species' benthic habits and physical structure. Demersal fish are not usually caught in surface gill nets, while trawls and seines are more easily avoided by large fish. White suckers ranged from 25 to 604 mm in samples from all gear, but most fish caught were between 300 and 500 mm.

White sucker adults were not captured during April from 1978 to 1980 (in 1977, sampling did not begin until June). In April white suckers spawn in streams, and thus might not be expected to occur in Lake Michigan samples (Fig. 86). By May, 1977-1980, many adults had emerged from the streams and many had spent gonads. The greatest catches during May were at stations C (6 m, south) and D (9 m, south).

June catches of white suckers during the 4 yr were similar in number to May; a greater proportion of fish had only slightly developed gonads, indicating spawning was largely finished by that time. In 1977 and 1979, July catches were high (Fig. 86), particularly at stations A (1.5 m, south) and B (3 m, south). Upwellings of cooler water occurred in July of both years and possibly led to an inshore movement of suckers. In 1978 and 1980 catches of adult white suckers in July were similar to June catches.

In August the number of white suckers captured appeared to vary inversely with water temperature; in 1977 and 1980 August catches were high at lower temperatures, while in 1979 water temperatures were warmer in August than in July and catches decreased (Figs. 86, 22). From 1978 to 1980, highest catches of white suckers occurred in September, with relatively high numbers observed in 1977 as well. In 1977 the September catch was highest in the nearshore zone (beach to 3 m), while in other years white suckers were more abundant at 3-12 m. Fish with well developed gonads generally began to appear more frequently in September.

In October, November and December white suckers appeared to have moved offshore, beyond our sampling stations. In all 4 yr the numbers of white suckers taken during these months were much lower than in September (Fig. 86).

White suckers were captured much more frequently at night than in the daytime. Water temperatures at which suckers were captured ranged from 4.0 to 25.9 C; in 1980 highest catch was at 14 to 16 C, while in 1979 large catches were observed at somewhat lower temperatures, 9-13 C. In 1978 white suckers were captured at higher temperatures with most caught at 18-19.9 C. In 1977, white suckers were captured primarily at water temperatures of 6-12 and 18-22 C; fish of the same size were caught at both temperature ranges. Relative

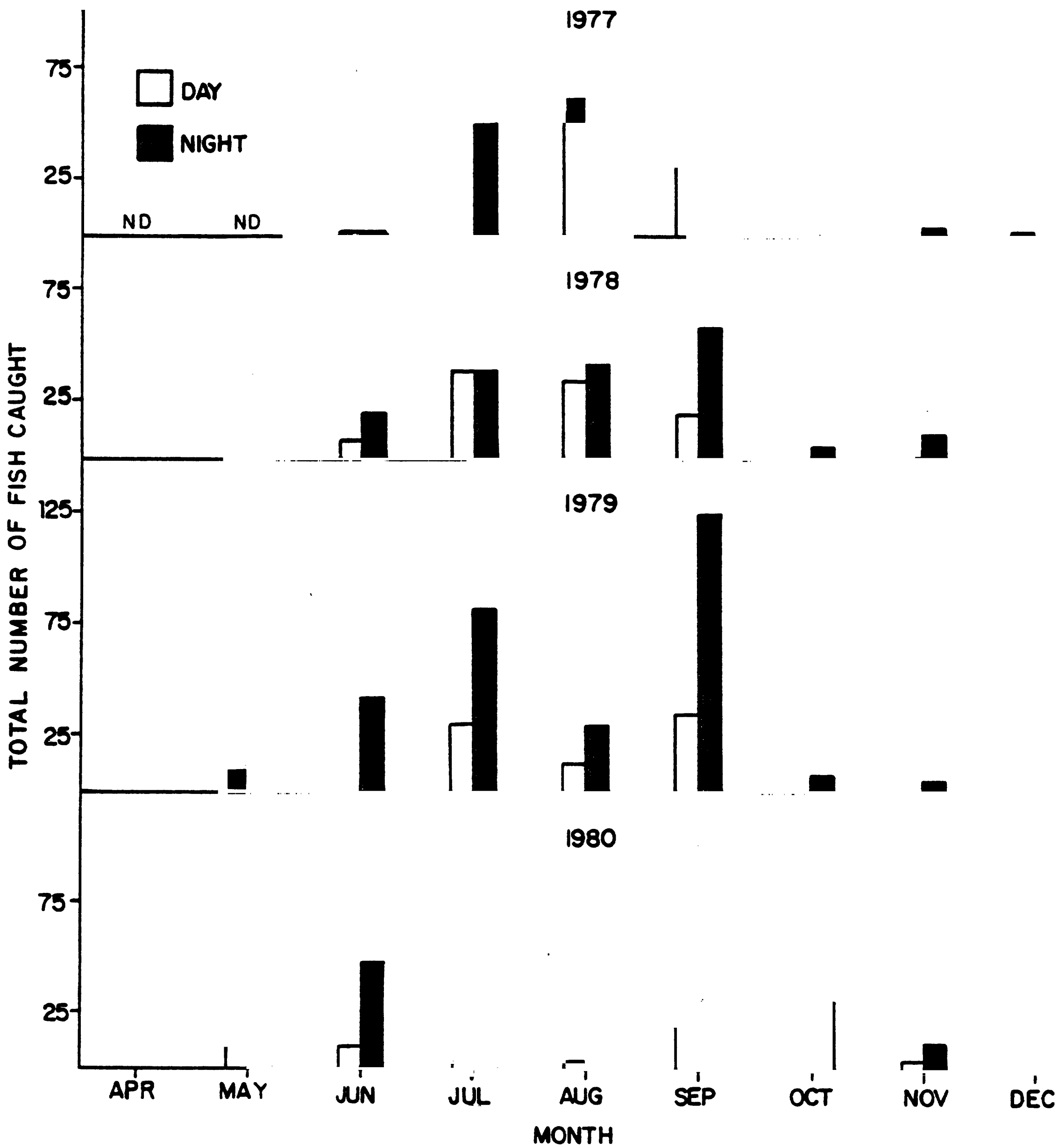


Fig. 86. Number of white suckers collected by all gear during day and night sampling once per month June to December 1977 and April to December 1978-1980, near the J. H. Campbell Plant, eastern Lake Michigan.

scarcity of fish caught between 12 and 18 C in 1977 may be due to less frequent occurrence of these temperatures during 1977 sampling periods, rather than actual temperature preference by white suckers.

In the vicinity of the D. C. Cook Power Plant, more female than male white suckers were collected (62% females in 1973 and 69% in 1974) (Jude et al. 1975). However, in the Campbell Plant study areas the sex ratio was more balanced, with 50 to 53% females collected during 1977-1980.

Neoplastic lesions have been observed on the heads, usually the lips, of white suckers in southeastern Lake Michigan (Jude et al. 1979b). Lesions were found infrequently on fish caught in our study; six were observed in 1979 and one in 1980.

Plant Effects--

Plant impacts were difficult to assess, since the number of white suckers caught was insufficient for statistical analysis. Sucker larvae were so seldom encountered in field sampling that no comparisons can be made between transects. However, data for all 4 yr show five times as many adult white suckers were caught at south reference transect station C (6 m) as at north transect station L (6 m). Also, studies in the vicinity of the D. C. Cook Plant indicated that more white suckers were caught at the reference transect than in the vicinity of the plant (Jude et al. 1979b). White suckers usually prefer cooler waters; however, water temperatures were not consistently higher at the north transect. In the latter years of the study, construction activity may have caused white suckers to avoid the north transect area, but we feel that the south transect area was in some way more attractive to white suckers than the plant transect.

<u>Johnny Darter</u>

Introduction--

Although not classified as a major species in terms of numbers of fish caught, johnny darters were among the top 10 species in numerical abundance during the period 1977-1980. This demersal species was caught almost exclusively in bottom trawls in Lake Michigan during the preoperational study period, mostly at night. Because of their size and shape they are not caught by our gill nets. Their near absence from beach seine hauls during 1977-1980 suggests little use of the beach zone.

Larvae--

During the 4-yr preoperational study, adult johnny darters were quite common in the study area; however, collections of darter larvae were infrequent compared with adult catches. Winn (1958) reported that johnny darters spawn under rocks, logs and other objects and that the young are guarded by the adults. Therefore, the larvae may not be very susceptible to

our sampling gear. One larva each was caught in 1977 and 1978, 9 in 1979 and 105 in 1980. Distributional patterns of larval johnny darters were only evident in 1980, the year of their greatest abundance.

The first occurrence of johnny darter larvae in 1980 was during early June at the 6-m south station. Densities of 32 larvae/1000 m^3 were noted at this time (Appendix 9). During late June, 1980, nearly 70 larvae/1000 m^3 were found at the north transect beach station Q (Appendix 8). In early July, 1980, densities of 30-70 johnny darter larvae/1000 m^3 at the 9-, 12- and 15-m north transect stations were observed (Appendix 8). Late July sampling in 1980 revealed johnny darter larvae again at north transect 6-, 9-, 12- and 15-m stations; the highest density (87 larvae/1000 m^3) occurred at the 9-m station. Water temperatures were nearly equal at all of those stations, ranging from 20.3 to 25.3 C. Johnny darter larvae were also caught at south transect 9- and 12-m stations with densities of 57 and 267 larvae/1000 m^3 respectively at this time. Water temperatures were approximately 21 C at the bottom stratum where johnny darter larvae were collected at both stations.

During early August 1980, johnny darter larvae were caught at both transects with the highest density of the year occurring at 9 m, north (1700 larvae/1000 m^3). Concurrently, densities of 828 larvae/1000 m^3 were found at the 9-m south station. Although johnny darter larvae were caught at both transects in late August 1980, highest densities were found at north transect stations; 625 larvae/1000 m^3 at 9 m north in contrast to 197 larvae/1000 m^3 at 9 m south. During September 1980 low densities (87 and 26 larvae/1000 m^3) of johnny darter larvae were found at 1.5- and 6-m north stations.

Johnny darters in Lake Erie hatched at 5.0 mm TL (Fish 1932). Our data showed that johnny darter larvae caught in early June had a mean length of 5.6 mm indicating they were newly hatched. Occurrence of 6.2-mm larvae in early July indicates that hatching and spawning were taking place at that time. A median length of 6.2 mm in mid-July suggests that spawning and hatching continued through July 1980. By mid-August 1980 median size of johnny darter larvae had reached 11.7 mm, suggesting that spawning had halted by that time. By mid-August the median size had reached 16.5 mm and increased to 24.5 mm by September.

Adults--

<u>Seasonal distribution</u>--

Introduction--During the study period (1977-1980) a predictable pattern of inshore and offshore movement was exhibited by adult johnny darters. A pre-spawning movement to inshore waters was quite evident by May. Jude et al. (1975, 1979b) documented that johnny darters spawn during late May, June and July in southeastern Lake Michigan. After spawning, a movement to deeper water was observed. The majority of johnny darters during July and August were caught at 6- and 9-m depths during the 4-yr study period. As autumn approached, a movement to deeper water began. Most fish collected during September and October were trawled at the 9- and 12-m contours. Catches

declined during November and December with most caught at 12 and 15 m. Although collections were not attempted during January-March, it is suspected that johnny darters inhabit water beyond the 15-m depth contour.

April--During 1978 no johnny darters were caught in April. Small catches of johnny darters occurred during April 1979 and 1980; less than 25 fish were caught. These fish were trawled at 9 and 12 m indicating that the bulk of the population was in water deeper than 15 m.

May--Increased numbers of johnny darters entered the study area in May. During 1980, May was the month of maximum catch for the entire year; 80 fish were caught and all but one were adults (34-57 mm), most likely moving inshore to spawn.

June and July--After spawning, johnny darters move into deeper water overlying sand and gravel (Winn 1958). This pattern appeared to be exhibited near the Campbell Plant. During June 1977, 116 johnny darters were collected; of these; 86 were trawled at 6 and 9 m. During June 1978-1980 the largest catch was also at 6 m with a few caught at 9 m and none beyond 12 m. July catches during 1977-1980 were much like June with concentrations at 6 and 9 m. Jude et al. (1975) found a similar distribution of johnny darters near the Cook Plant in southeastern Lake Michigan. All fish caught in June and July were adults.

August-December--During August johnny darters were noted at 6, 9 and 12 m. None were caught at 15 m during 1977-1980. Densities of johnny darters increased with depth from September to December. During September catches were almost all at the 9- and 12-m contours. The bulk of the October and November catch during 1977-1980 was collected at 12- and 15-m, while in December largest catches occurred at 15-m.

Johnny darters were caught primarily at night (85% of the 1977-1980 catch) and most (95%) were adult fish 40-70 mm. Johnny darters were caught at water temperatures from 4 to 23 C in Lake Michigan during the period 1977-1980. This wide range of temperatures indicates johnny darters exhibit no distinct preferred temperature. Movement to a preferred seasonal depth in contrast to distribution governed by temperature preference is indicated by data collected from 1977 to 1980. Gonad development data collected over the preoperational period showed a near equal sex ratio of 317 females to 271 male johnny darters.

Plant Effects--

The large increase in johnny darter larvae observed in 1980 was most likely the result of the riprap at the north transect where darter larvae densities were markedly higher. The riprap is ideal habitat for adult johnny darters providing both foraging and spawning habitat. SCUBA observations confirmed the increased abundance of johnny darters on the riprap; they are one of the most frequently observed fish. Preliminary observations in 1981 noted densities as high as 40 johnny darters/m² on the riprap. Jude et al. (1979b) reported an increase in johnny darters on the riprap at the Cook

Plant in southeastern Lake Michigan. There surely will be an increase in numbers of johnny darters in the study area due to the riprap. Additionally, the spawning habitat in the area immediate to the intake may result in considerable entrainment of johnny darters by Unit 3.

Emerald Shiner

Introduction--

The emerald shiner is a pelagic species inhabiting lakes and large rivers. Emerald shiners are characterized by considerable fluctuations in abundance (Scott and Crossman 1973). In Lake Michigan emerald shiner populations drastically declined from extreme abundance in the 1950s to scarcity in the 1960s, coincident with the increase in alewife populations (Wells and McLain 1972). Emerald shiners and alewives are both shallow-water planktivores, thus their population interactions may be due to competition for food (Smith 1970) or predation by alewives on the eggs and larvae of the shiner (Crowder 1980).

Emerald shiners spawn from June to August in Lewis and Clark Lake, South Dakota (Fuchs 1967) and western Lake Erie (Flittner 1964). Spawning in Lake Erie occurred inshore, over clean sand and hard, mud bottoms. First evidence of spawning was not observed until lake surface temperatures exceeded 22 C (Flittner 1964).

Emerald shiners exhibit schooling behavior with schools of YOY moving inshore in autumn. Groups of adults stay offshore in summer and overwinter in deep water (Scott and Crossman 1973).

In our study emerald shiners were uncommon in Lake Michigan, comprising less than 0.06% of the catch from 1977 to 1979. In 1980, however, the proportion of emerald shiners increased to 0.29% of the total catch. Two hundred forty-seven were collected in adult sampling gear in 1980, compared with 1 in 1977, 50 in 1978 and 7 in 1979.

Spawning of emerald shiners in Lake Michigan was not documented by our study, though it undoubtedly occurred in times of population abundance, prior to 1960. Areas of Pigeon Lake influenced by Lake Michigan offer suitable habitat for emerald shiner reproduction (Jude et al. 1980). Many YOY were collected in October 1978 and yearlings were collected in spring 1979 in Pigeon Lake, indicating a strong year class was produced in 1978. This timing coincides with a relatively low catch of alewives in 1978, while in 1977 and 1979 alewives were abundant and YOY emerald shiners less so. This suggests possible competition between the two species. Size of the Lake Michigan catch may also reflect the strong 1978 year class produced in Pigeon Lake. However, the characteristic irregularity of emerald shiner abundance and their schooling behavior may account for this apparent increase. At times, schools of emerald shiners may have inhabited the study area but were not captured.

Larvae--

Analysis of emerald shiner larvae data is complicated by the difficulty of identification at early stages. In 1977 and 1978, all minnow larvae less than 9 mm (except carp) were classified as unidentified Cyprinidae. By 1979, characters were defined for separating emerald shiners, spottail shiners, golden shiners and bluntnose minnows. Therefore in 1979 and 1980 more emerald shiner larvae were identified from our collections than in 1977 and 1978.

In 1977 no emerald shiner larvae were identified. A few were collected from late June to late July, 1978, at the south transect, to a depth stratum of 8.5 m at stations 1 to 15 m in depth. In 1979 and 1980, 17 emerald shiner larvae were collected, providing more data for interpretation than the first 2 yr.

In 1979 emerald shiner larvae were taken from Pigeon Lake on 14 May, somewhat earlier than in Lake Michigan. The earliest in the season an emerald shiner larva was collected from Lake Michigan was on 3 June 1980 at beach station R (north discharge). The specimen was 5.2 mm, collected soon after hatching. Newly hatched emerald shiner larvae were also collected 20 June 1979, 2 July 1980 and 18 August 1980 at north transect stations 1 to 9 m in depth. This indicates a spawning season from June to August, which is similar to that found by Fuchs (1967) and Flittner (1964). The highest densities were at beach station R (north discharge), up to 585 larvae/1000 m^3. Older larvae were collected from beach stations out to 15-m stations F and W, but at deeper stations the larvae were found at the surface or in strata above the thermocline. Slightly more larvae were collected at night than during the day. Emerald shiner larvae were collected at water temperatures from 8.9 to 24.5 C. Since many were captured at water temperatures below 22 C, and such cool temperatures are not conducive to spawning (Flittner 1964), larvae found in Lake Michigan may have originated in Pigeon Lake or the discharge canal.

Young-of-the-Year--

Emerald shiners less than 50 mm in August through November were assumed to be YOY from age-growth data presented by Fuchs (1967) and Flittner (1964). YOY emerald shiners were captured by seine in Lake Michigan in 1978 and 1980. During the 4 yr, no YOY emerald shiners were taken in trawls or gill nets. In 1978 most were found at beach station Q (south discharge), while in 1980 most YOY were at beach station R (north discharge). Only one YOY was collected at beach station P (south reference) during the 4 yr. YOY were found from August to November in our study. August or September was the earliest that YOY shiners were large enough to be susceptible to seining; the smallest emerald shiner collected by seine was 28 mm.

Most YOY emerald shiners were captured at water temperatures from 6 to 19 C. Cooler temperatures at time of collection may reflect abundance and schooling of young shiners during autumn months, rather than a temperature preference.

In 1978 YOY emerald shiners were abundant in Pigeon Lake (Jude et al. 1980), particularly at sandy beach station S (influenced by Lake Michigan). Connecting inland waters may provide a suitable habitat for growth of young emerald shiners.

Yearlings--

In Lake Erie, approximate minimum size at maturity is 50-60 mm and most emerald shiners spawn in their second summer (Flittner 1964). Therefore fish larger than about 60 mm might be expected to spawn. However, in our study many emerald shiners smaller than 80 mm showed no gonadal development. There are two possible reasons for this: (1) emerald shiners deteriorate rapidly so that gonads may not be easily seen; and (2) emerald shiners may take longer to reach maturity in Lake Michigan than in Lake Erie. Evidence for slow growth was provided by observations in April and May of numerous emerald shiners 20-44 mm in Pigeon Lake and in Little Pigeon Creek, 6 km north of the Campbell Plant. Emerald shiners this size cannot be YOY so early in the season so they were assumed to be yearlings. These yearlings overwinter at a smaller size than emerald shiners studied in other areas (Fuchs 1967; Flittner 1964).

Few emerald shiners of any size were collected in the spring in Lake Michigan during our study. Most yearlings may remain in connecting inland waters during the spring. Three emerald shiners 63-64 mm collected in June 1978, one in April 1979 (50 mm) and one in April 1980 (42 mm) were probably yearlings. By August, when emerald shiners occurred more frequently in our samples, yearlings would have attained sufficient growth to be indistinguishable from 2- and 3- year-old fish.

Adults--

As was observed with YOY and yearlings, adult emerald shiners were collected exclusively by seine during our study. They ranged from 70 to 104 mm in length. Few were found in our samples from April to July; they were most abundant August and September and in 1980 continued to be common in October and November. Since fish larvae data indicate spawning was mostly prior to August, the late summer-fall aggregations were not for the purpose of spawning. Indeed, their gonads showed only slight to moderate development, although those in poor condition or classified as immatures could have been spent. In 1980, for example, only about 20% of the emerald shiners captured in seines showed visible gonad development and most of those were only slightly developed. Presumably, then, adult emerald shiners spawn in June and July elsewhere than in Lake Michigan, probably Pigeon Lake or other inland waters. Spawning grounds in our study area have not been discovered, although high densities of larvae were noted at station S in Pigeon Lake (Jude et al. 1979a). During the 4 yr, 23 females and 27 males were collected in Lake Michigan.

Emerald shiners usually spend summer months offshore, schooling near the surface (Scott and Crossman 1973). Thus they may not be susceptible to our sampling gear at deeper stations (beyond 6 m). Even if emerald shiners are

present offshore in the summer, they probably do not spawn there, since water temperatures are cool and Flittner (1964) reports they spawn in 3-6 m of water.

From 1977 to 1979, approximately as many emerald shiners were collected at night as in the daytime. In 1980, however, almost three times as many shiners were taken at night.

Emerald shiners were collected at water temperatures from 7.3 to 25.7 C. Abundance seemed to be related more to season and habitat than temperature.

Plant Effects--

More emerald shiners were captured at beach stations R (north discharge) and Q (south discharge) than at beach station P (south reference) during the study. This is more likely due to the use of Pigeon Lake for a spawning and nursery area than attraction of emerald shiners to the thermal plume. However, it may be that emerald shiners are attracted to the warmer water as well.

Ninespine Stickleback

Introduction--

The ninespine stickleback is widely distributed in fresh and salt waters, and is common in the Great Lakes basin (Scott and Crossman 1973). It is, however, not as abundant in southeastern Lake Michigan as it is farther north (Wells 1968; Griswold and Smith 1973). Its distribution in the more northerly sections of Lake Michigan may be due to its preference for cooler, deeper water (Wells 1968; Nelson 1968; Dryer 1966). Although ninespine sticklebacks frequently nest in vegetation, they have also been observed spawning in areas devoid of rooted aquatic plants. In such cases they may use bits of algae and detritus to build nests (McKenzie and Keenleyside 1970). Spawning occurs from April to August in Crooked Lake, Indiana (Nelson 1968), and in June and July near the Apostle Islands, Lake Superior (Griswold and Smith 1973). Studies of ninespine stickleback seasonal distribution show variation by study area; however, in most areas ninespine sticklebacks overwinter in deep water (Griswold and Smith 1973; Nelson 1968).

Ninespine sticklebacks spawn in two different habitats in the Campbell Plant vicinity: Pigeon Lake (Jude et al. 1979a) and Lake Michigan, demonstrating that spawning requirements were met in both environments. The extent to which the inshore area of Lake Michigan near the Campbell Plant was used for a spawning and nursery area is thought to be slight due to the scarcity of larvae in our samples. Ninespine sticklebacks comprised between 0.1 and 0.5% of the total adult and juvenile catch during the 4 yr. In adult sampling gear 133 were collected in 1977, 414 in 1978, 373 in 1979 and 236 in 1980. No trend in abundance could be detected.

Larvae--

Ninespine stickleback larvae were more frequently collected in 1980 than in previous years, possibly due to utilization of Campbell Plant riprap for spawning. Two unidentified sticklebacks taken in 1977 (Jude et al. 1978) are now known to be ninespines, based on our increased expertise at identifying larval sticklebacks. Abundance of ninespine stickleback larvae found in our samples gradually increased during the study to 26 in 1980. The nest building habit of adult sticklebacks as well as the protection of the eggs and larvae by the adult male stickleback is probably in part the cause for generally low densities of larval sticklebacks in our samples. Additionally, we feel that the inshore area (beach to 15 m) of Lake Michigan near the plant is not used extensively as a spawning and nursery area.

Ninespine stickleback larvae were most effectively collected by sled tows. During the study 17 sled tows contained stickleback larvae, compared to only 7 net tows. This probably reflects the demersal habit of larvae. Densities ranged from 19 to 1452 larvae/1000 m^3 for sleds and from 9 to 370 larvae/1000 m^3 for net tows.

Larval ninespine sticklebacks were collected from the beach zone (station P, south reference) out to 15-m stations F (south) and W (north). However, shallow water appeared to be inhabited only by larger, older individuals (7.5-20 mm). Small larvae soon after hatching (4.7-6.0 mm) were collected at deeper stations (12-15 m) but were taken infrequently, probably because the male keeps the young in the nest for up to 2 wk (Scott and Crossman 1973). Older larvae were collected at a variety of depths. These data indicate spawning in 12-15 m (and deeper) water and subsequent dispersal of larvae. Lengths of stickleback larvae in our samples ranged from 4.7 to 20.2 mm.

Ninespine stickleback larvae were collected from 1 July to 19 September, most frequently in July. Sizes of larvae indicate probable spawning from late June to late August. Water temperatures at time of collection ranged from 4.7 to 25.2 C, including temperatures over 20 C for newly hatched larvae. Griswold and Smith (1972) found temperatures 11-12 C triggered spawning in the laboratory; however, in our study the temperature at which sticklebacks spawned could not be determined.

Young-of-the-year--

Length of ninespine sticklebacks after one growing season is approximately 45 mm in Lake Superior (Griswold and Smith 1973) and 35 mm in streams in Europe (Jones and Hynes 1950). Therefore, fish less than 35 mm in late summer and less than 45 mm in autumn were considered YOY. A few YOY were collected each year of the study, 15 in all. They were captured in trawls from July to November, mostly at south transect station F (15 m) and some at stations N (9 m, north), D (9 m, south) and E (12 m, south).

Adults--

Ninespine sticklebacks may spawn after 1 yr of life (Jones and Hynes 1950). During our study yearlings could not be distinguished from older age-groups by size or distribution. For these two reasons yearling ninespine sticklebacks will be discussed together with adults.

Most ninespine sticklebacks were collected May through August, which includes their spawning time. This species spends winter in deep water and moves inshore to spawn (Griswold and Smith 1973). In our study, few were collected in April (Fig. 87, Appendix 7), probably because they were farther offshore than our deep stations. By May an inshore movement had begun. Catches at north transect stations L (6 m) and N (9 m) resembled those of south transect stations C (6 m) and D (9 m) respectively.

In May ninespine sticklebacks were distributed uniformly among our sampling stations (Fig. 87). Most sticklebacks in May showed only slight to moderate gonad development (Fig. 88), although in May 1978 ripe-running ninespine sticklebacks were collected in Pigeon Lake (Jude et al. 1979a). In June and July a large proportion of fish had well developed or ripe gonads. Spent fish occurred mostly in July and August (Fig. 88). In June and July ninespine sticklebacks were collected from the beach zone to 15 m; however, they were most numerous from 9 to 15 m (stations D, E, F and N). This observation correlates with collection of ninespine stickleback larvae at 12-15 m, indicating spawning in Lake Michigan's open water. During the 4 yr, ninespine sticklebacks were most abundant at station E (12 m, south).

In all 4 yr ninespine sticklebacks apparently moved out of our study area after spawning. The occurrence of ripe-running or spent fish was followed a month later by their near disappearance from our samples. In 1977 abundance dropped sharply after June; in 1978 and 1980 after August and in 1979, ninespine stickleback abundance decreased after July (Appendixes 7, 27, 28 and 29). There was a tendency for ninespines to be more concentrated at deeper stations from late summer through fall (Fig. 87). They were scarce at all of our stations from September to December, 1977 to 1980. None were collected in December at the south transect. However, two were taken at north transect stations L (6 m) and N (9 m) in December 1979 and 1980 respectively.

Nearly all ninespine sticklebacks collected during our study were taken by trawl, but a few (20) were collected by seine at beach stations. Their preference for deep water and their small size makes them most susceptible to capture by trawl. Ninespine sticklebacks collected by trawl and seine ranged from 15 to 84 mm in total length, although fish from 15 to 44 mm were considered to be immatures. Ninespine sticklebacks were more frequently collected at night than during the day; 82% of all sticklebacks were taken in night samples during the 4 yr.

Ninespine sticklebacks were collected at water temperatures from 1.0 to 22 C. The July 1979 upwelling, which depressed water temperatures below 5 C, did not immediately decrease catches. It may, however, have depressed spawning, since in the following month (August) sticklebacks were scarce and

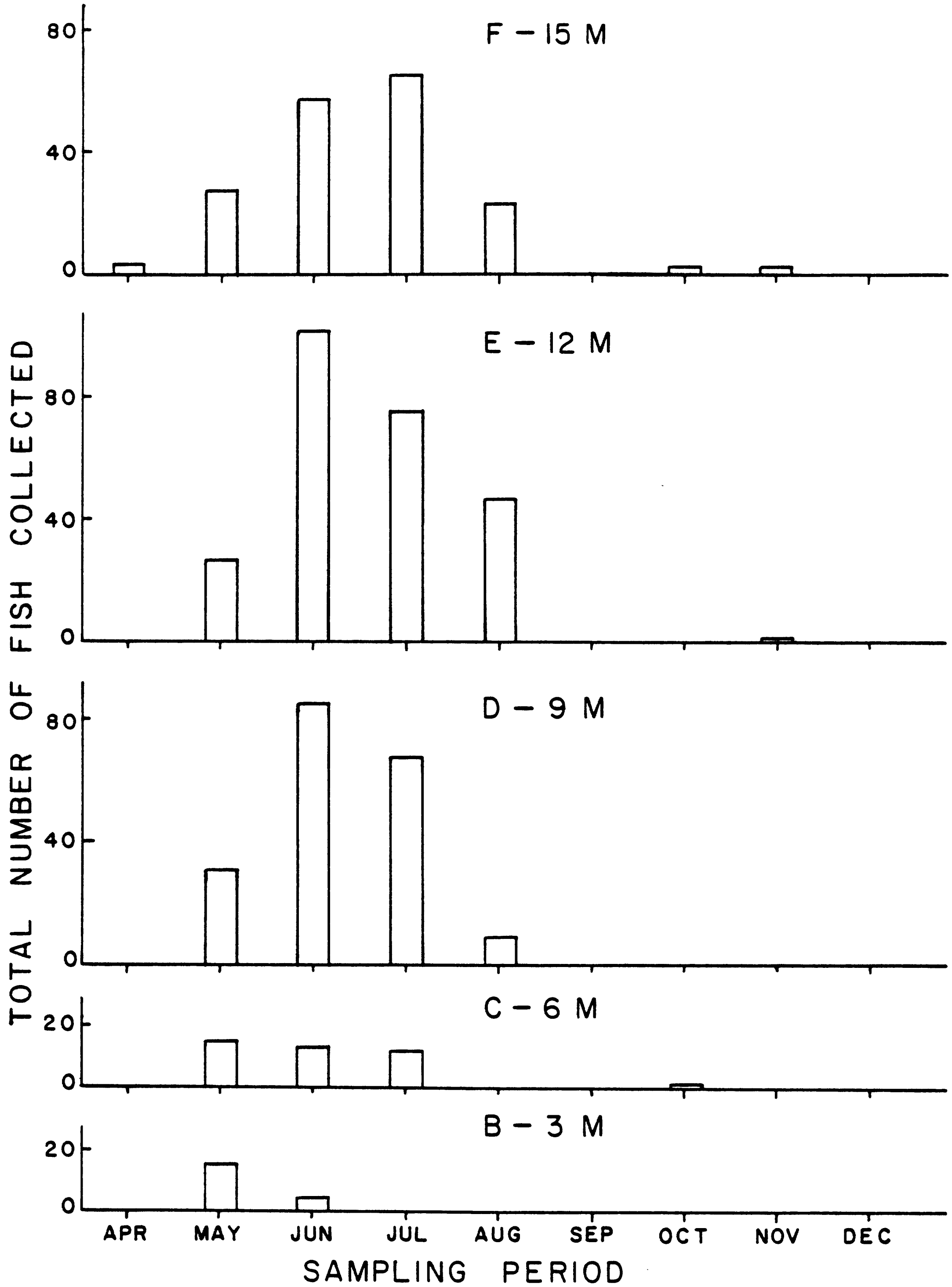


Fig. 87. Total catches of ninespine sticklebacks by month for south transect stations B (3 m) through F (15 m) near the J. H. Campbell Plant, eastern Lake Michigan, 1978-1980. The 1977 data are not included because sampling was not conducted in April and May.

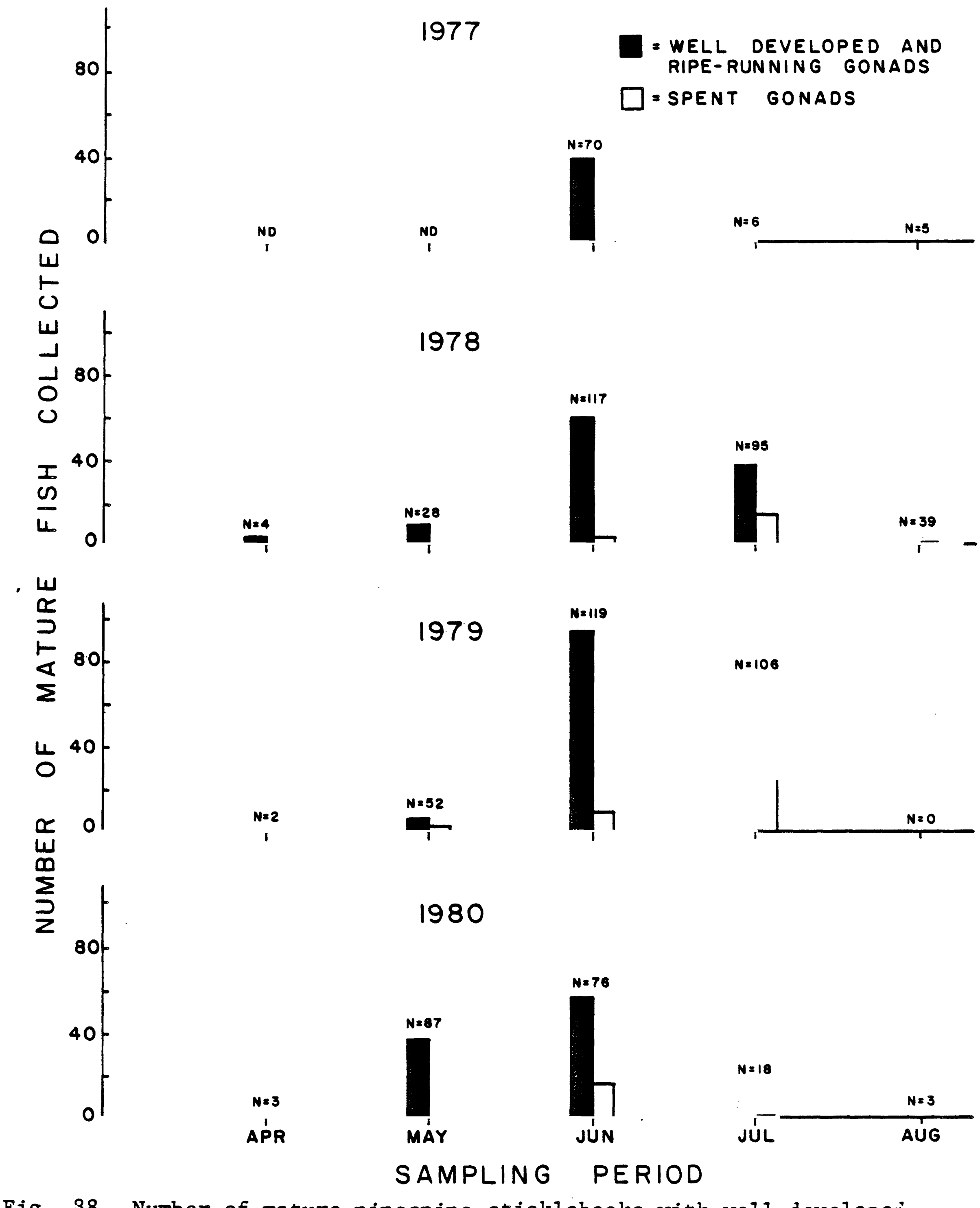


Fig. 38. Number of mature ninespine sticklebacks with well developed, ripe-running and spent gonads collected monthly during June-December 1977 and April-December 1978-1980 near the J. H. Campbell Plant, eastern Lake Michigan. N = total number of mature ninespine sticklebacks caught per month.

had probably moved offshore as they do after spawning. Preferred temperatures appear to be 6-14 C from our data. There was no apparent spatial separation related to water temperature.

An unusual sex ratio was observed in our study. Females far outnumbered males, 663 to 184. Since ninespine sticklebacks are small fish, the poor condition of gonads may have resulted in some males with small gonads being classified as immatures. However, if all immature and deteriorated fish are added to the male category, the total is still only 372, which would still result in a skewed sex ratio. This sex ratio may be related to the spawning habits of the species. Males construct and guard nests, while up to seven females may deposit eggs in a single nest (Scott and Crossman 1973).

During our study eight ninespine sticklebacks were found to be infected by an acanthocephalan, probably Leptorhynchoides thecatus. Six of the fish were females and two were males. They ranged from 65 to 74 mm in length.

Plant Effects--

As previously stated, catches of ninespine sticklebacks at the north transect were similar to catches at stations of equal depth at the south transect. A minimal difference of two fish captured in December near the plant while none were taken in December at the reference transect was observed. It is unknown whether the intake structures themselves and associated riprap will encourage additional spawning of ninespine sticklebacks there in the future. However, any algal growths and trapped debris on the riprap would supply additional nesting material. If the availability of additional nesting material causes increased use of the area for spawning, larval sticklebacks may become more common near the Campbell Plant.

Longnose Sucker

Introduction--

Longnose suckers were the twelfth-most common species captured in 1980; 166 individuals were taken, comprising 0.20% of the total catch (Table 10). Of the 4 yr, longnose suckers appeared to be most abundant in the study area in 1979, when 208 were captured (0.27% of the total catch). In 1977 and 1978 they were more scarce; only 36 and 73 were captured respectively (0.05 and 0.08% of the total catch). These data imply an increase in abundance over the last 4 yr. A slight increase in numbers of longnose suckers was also observed in the vicinity of the D. C. Cook Plant between 1977 and 1980 (unpublished data, Great Lakes Research Division).

Longnose suckers in Lake Michigan, like white suckers, usually spawn in April in tributary streams (Becker 1976). Few catostomid larvae were captured during this study, and white suckers were more abundant than longnose; therefore longnose sucker larvae were probably not captured in Lake Michigan during this study (see RESULTS AND DISCUSSION, White Sucker).

Young-of-the-Year and Yearlings--

Age-growth data (Koehler 1978) for Lake Michigan near Ludington were used to separate YOY (10 to approximately 150 mm) and yearling (150 to 264 mm) longnose suckers from adults. Eleven YOY longnose suckers were captured from 1978 to 1980. They were caught from June through September in trawls and seines from the beach to the 6-m contour. YOY ranged in size from 35 to 124 mm. Three yearling longnose suckers, 155 to 174 mm, were captured at the 6-m contour in September and October 1978 to 1980. A probable yearling, approximately 80 mm in May, was seined in 1978 at beach station Q (south discharge).

Adults--

Adult longnose suckers were captured most effectively by bottom gill nets; fish 225 to 624 mm were caught during the 4 yr. A few longnose suckers were captured in trawls, seines and surface gill nets, but adult suckers can often avoid trawls and seines, and their benthic habit prevents many from being caught in surface gill nets.

Longnose suckers were generally scarce in April samples, due to spawning migrations to streams. By the May sampling period, longnose suckers had returned to Lake Michigan and in some years showed peak abundance during that month. Many of these had spent gonads. In summer months, abundance of longnose suckers fluctuated during the 4 yr. By late fall longnose suckers moved offshore and few appeared in our samples.

Longnose suckers, like white suckers, were most abundant in our samples collected near the 6-m contour. Exceptions to this distribution pattern occurred during midsummer upwellings of cooler water in 1977 and 1979. In those years longnose suckers moved inshore with the cool (8-12 C) water and were captured at the 1.5- and 3-m contours. Longnose suckers were found at water temperatures ranging from 4 to 24 C, and appeared to prefer temperatures between 8 and 16 C. Night samples yielded larger numbers of longnose suckers than day samples.

More male longnose suckers were collected during the study than females (244 males, 204 females). However, this difference was not consistent during the 4 yr. Individuals with spent gonads were observed as early as April (1980) and as late as July (1979).

Plant Effects--

Longnose suckers were more abundant at reference station C (6 m, south) than at station L (6 m, north). Total bottom gill net catch from 1977 to 1980 at reference station C (6 m, south) was 104 longnose suckers, while at station L (6 m, north) catch was only 24. This catch difference existed all 4 yr of the study; possible reasons for lower catch at plant stations include construction activity and presence of riprap at the plant structures. Fish may also prefer south transect habitat over that available in the vicinity of the plant. However, water temperatures at times of sampling were not

consistently warmer at the north transect (see RESULTS AND DISCUSSION, White Sucker). Interestingly a similar relationship (more fish at the south transect) was also documented for white suckers.

Slimy Sculpin

Introduction--

The occurrence of slimy sculpins in the inshore zone of Lake Michigan near Port Sheldon was highly correlated with water temperature. Our study indicates that slimy sculpin were rarely caught at water temperatures exceeding 10 C, and were most frequently caught at water temperatures of 7 C or less. These results compare well with those of Rottiers (1965) who indicated a preferred water temperature of 6 C for slimy sculpin and Wells (1968) who reported that this species was most frequently caught at temperatures of 4-5 C. Additional data from Wells (1968) suggest that even during winter and spring months, the bulk of the slimy sculpin population inhabits depths greater than 18 m, and thus our sampling effort collected only from the fringes of the slimy sculpin populations of Lake Michigan. The major occurrences of adult slimy sculpin in the inshore zone were during April, May, December and periodically during summer months when cold-water upwellings occurred, which accommodated the thermal preference of this species.

The present importance of the slimy sculpin as forage for the salmonid fishery in Lake Michigan is difficult to determine. Prior to the invasion of the alewife, Van Oosten and Deason (1938) indicated that cottids comprised 72% by volume of the food of lake trout in southern Lake Michigan. The most dominant items in the stomachs of lake trout in the present study were smelt and alewives (see RESULTS AND DISCUSSION, Lake Trout). Thus, it appears that there is diminished importance of this species as forage since the invasion of the smelt and alewife, at least in the inshore zone. Our observations do confirm, however, at least some importance of sculpins in the diet of brown and lake trout during spring months when these species both occur inshore. Slimy sculpins in the area of Port Sheldon were reported to have an extremely high infection rate of the acanthocephalan Leptorhynchoides thecatus (Heufelder and Schneeberger 1980); however individual fish seemed unaffected by their presence.

Larvae--

Effective sampling of larval sculpins is made difficult by the nesting and protective behavior of the adults. Slimy sculpins have been observed spawning on the undersides of objects at depths to 12 m in the study area. When larvae hatch, they remain close to the protected nest area until approximately the time of yolk absorption. Remaining close to a protected area often affords protection from conventional sampling gear and explains the absence of newly hatched larvae (6-6.5 mm) in our samples.

Occurrences of larval slimy sculpins in our samples over the 4-yr period were sporadic and exhibited no evident trends. During 1977 only three slimy sculpin larvae (12-19 mm) were captured, all in late July. The occurrence of

slimy sculpin larvae in the 9.5- and 15-m strata of station H (21 m, south) resulted in estimated larval sculpin densities of 13-20 larvae/1000 m^3 and suggested that larval sculpins may be less demersal than adults. No larval slimy sculpins were captured in the study area during 1978. During 1979, sculpin larvae (8.5 - 16.5 mm) were sporadically present at various depth strata of the 9- to 15-m stations during both July sampling trips as well as during early August (Jude et al. 1980). There were no significant differences in the densities of larval sculpins between transects (13-167 larvae/1000 m^3) in 1979 and water temperatures at times of capture did not exceed 8.0 C.

Late June sampling during 1980 indicated a large dispersed aggregate of slimy sculpin larvae at the four surface-most strata of station O (12 m, north) (15-37 larvae/1000 m^3) and the two surface-most strata of station N (9 m, north) (21-40 larvae/1000 m^3) (Appendix 9). These larvae were small, 7-9 mm, and suggest that even larval sculpins with some remaining yolk may occasionally migrate toward surface strata. The remaining sporadic occurrences of slimy sculpin larvae in early July to late August 1980 were all recorded from sled tows at depths of 9 m or greater and resulted in densities of 29-240 larvae/1000 m^3.

Over the 4-yr period the majority of sculpin larvae were caught at night. This concurs with studies by Liston et al. (1981), near Ludington, Michigan and suggests either increased daytime net avoidance or a movement to protected, less accessible areas during the day.

Adults--

Slimy sculpins were most abundant in the inshore area during April and May 1978-1980. Greatest abundance was at the deeper 12- and 15-m stations, with progressive decline in abundance with shallower depths to 3 m. Slimy sculpins were rarely caught in the beach zone. Sculpins collected ranged in size from 15 to 114 mm.

The occurrence of slimy sculpins in the inshore zone is probably related to two factors, spawning instinct and water temperature. Gonad data for April-June, 1978-1980 indicate that spawning of slimy sculpins in the area of Port Sheldon occurs in April or May (Fig. 89). The exact date of spawning is probably temperature dependent. Slimy sculpins were reported to spawn at 5-10 C in New York (Koster 1936) and 8 C in the Montreal River (Van Vliet 1964). Rottiers (1965) observed that in Lake Michigan spawning occurred prior to early May in 1964, however, no water temperatures were given. A mass of slimy sculpin eggs was taken from a log which was trawled at station E (12 m, south) on 14 May 1979 at a water temperature of 11.2 C, however it is probable that these eggs were actually spawned at a lower water temperature. Thus it appears that the inshore zone is used by at least some sculpins as a spawning area. It is probable that although the bulk of the sculpin population is at greater depths during April and May, as indicated by Wells (1968), the search for suitable substrate on which to spawn causes some sculpins to disperse into areas not normally inhabited. This dispersal into the inshore zone is allowed by colder water temperatures in April and May of most years (generally below

10 C). Slimy sculpins generally prefer water temperatures less than 10 C (Rottiers 1965; Wells 1968). With the warming of inshore water in June, and the continuance of this trend in July - August, slimy sculpins were rare in the inshore zone. The exceptions to this trend were observed during times of upwelling, and times when bottom water temperatures at the deeper inshore stations were still within the temperature preferendum of the slimy sculpin. At these times varying catches of slimy sculpins were observed. There was also an occasional and sporadic occurrence of sculpins at inshore stations at warmer (greater than 10 C) water temperatures. The majority of these slimy sculpins caught at warmer water temperatures were smaller immature sculpins which we feel have a higher tolerance for warmer water compared with adults over 70 mm.

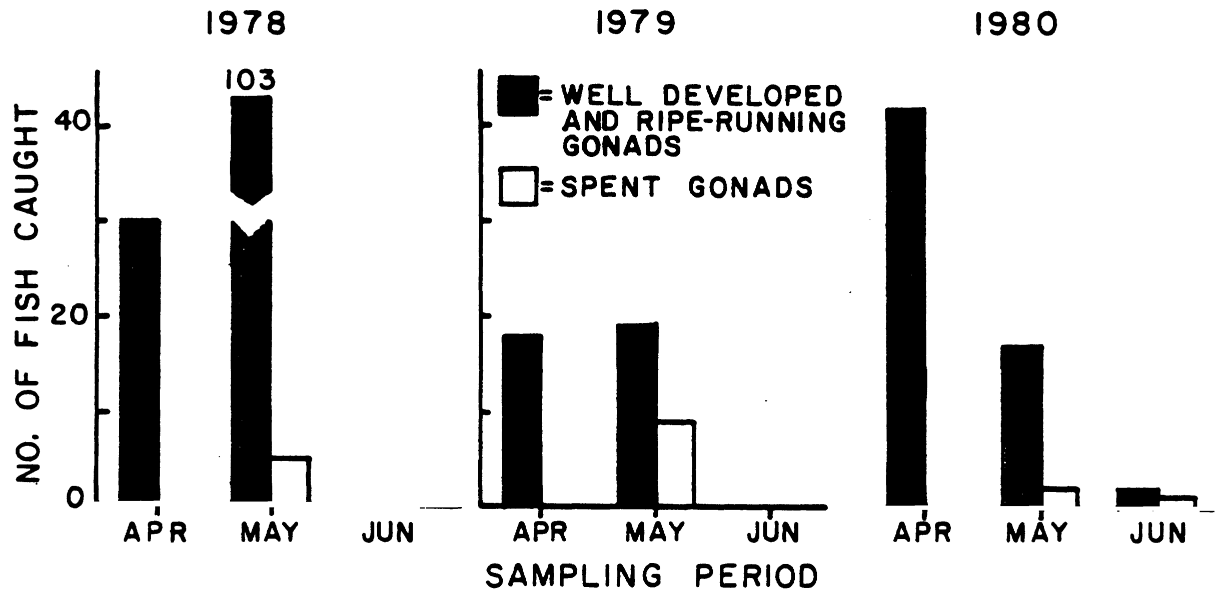


Fig. 89. Number of mature slimy sculpins with well developed, ripe-running and spent gonads collected monthly during April-December 1978-1980 near the J. H. Campbell Plant, eastern Lake Michigan.

The next major occurrence of slimy sculpins in the area of the Campbell Plant was typically during December when water temperatures were again within the temperature preferred by slimy sculpins. It is likely that throughout the winter months some slimy sculpins persist in the inshore zone; however, Wells (1968) suggests that the bulk of the population remains offshore.

Data from all years 1977-1980 showed that the majority of slimy sculpins were caught at night. Although the reasons are unclear, aquarium as well as diving observations indicate that sculpins exhibit a negative phototaxis, and often seek areas of cover during daylight hours. Slimy sculpins can also bury themselves in sand when no cover is provided.

Plant Effects--

Diving observations confirmed that the protective riprap area of the intake and discharge structure has provided a considerable expanse of spawning substrate for slimy sculpins. This increased spawning substrate in the area of the Campbell Plant structures may be responsible for the increased occurrences of sculpin larvae in 1979 and 1980 field samples compared with those taken prior to the placement of riprap in 1977 and 1978.

The increased spawning substrate provided near the intake structure as well as the occasional migration of larval sculpins off the bottom is expected to result in considerable entrainment of larval slimy sculpins during Unit 3 intake operation. The magnitude of the entrainment loss of slimy sculpin larvae is difficult to predict and will depend largely on the extent of continued use of the area by slimy sculpins as a spawning and nursery area. There is some indication, based on diving operations, that fewer sculpins utilized the area for spawning in 1980 compared with 1979.

The maximum entrainment loss of larval sculpins is expected to occur from June to July, based on a hatching time of late May - early June. Yolk-sac larvae remain relatively near the nest and are subject to less entrainment loss, so we expect the primary loss to be in larger larvae (larger than approximately 7.5 mm). Eggs of sculpin should not be entrained to any great degree since they are adhesive and laid in nests guarded by the male sculpin.

<u>Round Whitefish</u>

Introduction--

The round whitefish is widely distributed in North America and into northeastern Asia, primarily in deep lakes (Scott and Crossman 1973). It inhabits relatively shallow water, from surface to 25 m in Moosehead Lake, Maine (Cooper and Fuller 1945) and to about 45 m in the Great Lakes (Koelz 1929). Like lake whitefish, round whitefish have decreased in abundance in Lake Michigan since the early 1900s (Mraz 1964).

Round whitefish usually spawn in November in the Great Lakes region (Scott and Crossman 1973). Spawning habits are similar to those of lake whitefish (Machniak 1975). Spawning occurs in relatively shallow water, on silt-free substrate.

Collections of round whitefish in the Campbell Plant vicinity have increased during our study. In 1977, 8 were captured; in 1978, 10; in 1979, 44 and in 1980, 115. Percentage of round whitefish in the total catch likewise increased from 0.01% to 0.14% (Jude et al. 1978, 1979a, 1980). Spawning evidently occurs in our study area; spent fish, and greater abundance of round whitefish, have been observed in the fall.

Larval Coregoninae are difficult to identify to species. Possibly some round whitefish larvae have been collected in our study. For a discussion of this, see RESULTS AND DISCUSSION, <u>Unidentified Coregoninae</u>, Larvae.

Young-of-the-Year and Yearlings--

Great variation exists in growth rates of round whitefish throughout its range. Lake Michigan populations appear to grow faster than in other areas (Mraz 1964). Age-growth data from the Ludington area (Armstrong et al. 1977) and western Lake Michigan (Mraz 1964) were used to estimate age of our specimens. YOY round whitefish were collected only in July and August 1980. Ten fish 50-97 mm were trawled from depths of 3 to 15 m. All but one were from the south transect; however, this may be due to less trawling at the north transect. Nearly all YOY round whitefish were collected at water temperatures of 18-21 C, which was warmer than temperatures at which adults were collected.

Several fish 101-130 mm collected in fall may also have been YOY. These were taken at stations 6-15 m in depth, at the north and south transects, at cooler water temperatures than those taken in summer (6.8-12 C). There was no clear separation between lengths of YOY and yearling fish. Round whitefish 138 to 173 mm collected in late fall 1977 and 1980 may also have been yearlings. These were trawled (one was gillnetted) at north and south transect stations 6-12 m in depth, most at water temperatures of 4-5.5 C.

Adults--

Round whitefish were collected from April to December during our study at all stations where trawling or bottom gillnetting was conducted. In April and May they were found at a variety of depths. From June to August, however, round whitefish appeared to prefer deeper waters, primarily 9 to 15 m. From April to September round whitefish were not abundant; however, in October and November abundance increased dramatically, particularly at depths of 3 to 9 m (Appendix 6). During October and November, fish with well developed and spent gonads were collected, indicating spawning occurred inshore. In December mature round whitefish were nearly absent from our collections, apparently moving from their spawning grounds to deeper water.

Round whitefish usually mature sexually at approximately 340-360 mm (Mraz 1964). Immature fish older than yearlings were generally distributed with adults in our samples, except that they remained inshore in December, after spawning ended. Several round whitefish 225 to 350 mm had slight gonad development in the fall and probably would have spawned the following year.

More females (68) than males (46) were collected during our study. Sex ratios are usually 50:50 for round whitefish (Armstrong et al. 1977; Normandeau 1969). Our resulting 60:40 ratio may simply be due to small sample size.

Most round whitefish were collected by bottom gill net, and some by trawl. Trawls were more effective in capturing small fish, especially YOY. Total size range of round whitefish was 50 to 515 mm. Studies at Ludington (Armstrong et al. 1977) and western Lake Michigan (Mraz 1964) yielded round

whitefish up to 528 mm and 515 mm respectively; however, researchers in New Hampshire and Great Slave Lake seldom found round whitefish over 450 mm (Normandeau 1969; Rawson 1951).

Round whitefish were collected at water temperatures from 1.0 to 20.8 C, most between 5 and 14 C. At temperatures above 16 C only immatures (< 215 mm) were found. Most round whitefish were collected during the night; however, this trend was not as marked as for lake whitefish.

Round whitefish are benthic feeders, primarily consuming insect larvae and small gastropods (Armstrong et al. 1977; Rawson 1951). Stomach contents from round whitefish examined during our study included chironomid and caddisfly larvae, gastropods, amphipods and lake trout eggs. Round whitefish are known to consume their own eggs (Normandeau 1969); however, during our study trout eggs were prevalent in stomachs. From size, coloration and season these were judged to be lake trout eggs (Jude et al. 1980). In 1979 a few instances of egg predation occurred and in 1980 eight round whitefish were found with trout eggs in their stomachs, up to 50 eggs per individual.

During our study several round whitefish examined had parasitic copepods, which were probably *Salmincola edwardsii* (Hoffman 1967), attached to their gill filaments. In 1980 two fish (immatures 169 and 262 mm) were found to harbor acanthocephalans.

Plant Effects--

In 1977 through 1979 the number of round whitefish collected were approximately equal between north and south transects. However, in 1980, especially in autumn, more were collected at north transect stations L (6 m, south discharge), N (9 m, north) and U (6 m, north discharge) than reference stations C (6 m, south) and D (9 m, south). Bottom gill net catches for these stations were: C, 8; D, 8; L, 21; N, 13; and U, 10. The riprap laid down for the new offshore intake and discharge serves as spawning habitat for lake trout (Jude et al. 1981b) and round whitefish may be attracted to it for various reasons, including food (lake trout eggs), cover and spawning habitat.

Gizzard Shad

Introduction--

Gizzard shad utilize, at least seasonally, all of the types of aquatic habitat available near the Campbell Plant. Prior study of impingement samples at Units 1 and 2 (Jude et al. 1979a) indicated the year-round presence of gizzard shad in the discharge canal. The field catch of adult and juvenile gizzard shad in Lake Michigan near the Campbell Plant was 174 in 1977, 189 in 1978, 35 in 1979 and 111 in 1980, which accounted for less than 0.5% of the catch by number in any year. It is difficult to assess the degree to which gizzard shad utilize the area of the Campbell Plant as a spawning or rearing area. Our estimates of larval gizzard shad abundance are probably low due to the difficulty in distinguishing them from larval alewives at that point in development from after yolk absorption to fin formation. Observations in the

Pigeon Lake-Pigeon River system as well as Lake Michigan and the discharge canal lead us to believe that the primary site of shad reproduction is the discharge canal itself. Larvae found in Lake Michigan near the plant probably originated in the discharge canal or the Grand River.

Larvae--

The first occurrence of gizzard shad larvae in years 1979 and 1980 corresponds to our increased expertise in identifying them, rather than a sudden appearance in these years. Gizzard shad larvae were sporadically present from May or June to July in 1979 and 1980. Densities of larval gizzard shad at these times were low, not exceeding 150 larvae/1000 m^3 at any time. Field sampling of adults in Lake Michigan revealed no spawning activity of adults in the area, so an inland source of larval gizzard shad was implicated. Supplemental sampling in the discharge canal in May 1979 revealed high densities of larval gizzard shad and strongly suggests that the discharge canal was the source of larval shad sampled in Lake Michigan.

Young-of-the-Year, Yearlings and Adults--

YOY gizzard shad (up to 134 mm) over the 4-yr period occurred sporadically from August to December (Table 53). No distributional trends, however, were evident.

Yearling and adult gizzard shad were present in the area primarily from August to November, but occasional catches in all months except December were observed. During the entire study period the majority of yearling and adult gizzard shad were caught at depths of 6 m or less. Nearly all adult gizzard shad collected exhibited only slight or moderate gonad development. Fish with spent gonads occurred rarely during the study, appearing in July and August. These observations provide further evidence for spawning in the canal, rather than in Lake Michigan.

Gizzard shad were collected in all gear types utilized. Large gizzard shad were collected primarily by gill nets, while trawls and seines accounted for most smaller fish. Most were taken at night, at water temperatures exceeding 10 C.

Plant Effects--

Due to the low abundance of gizzard shad near the Campbell Plant, it is doubtful whether plant operation (Unit 3) will significantly affect their population or that the discharge of Units 1 and 2 was affecting their Lake Michigan distribution. Bodola (1966) has noted a tendency for shad to be attracted to warm-water discharges even during winter months; however, we have not seen any inordinate concentrations of gizzard shad near the Lake Michigan discharge thus far.

We feel that the substantial production of shad larvae in the discharge canal will undoubtedly continue in future years. Since warm water will be discharged at 6 m, some gizzard shad larvae will be discharged into Lake

Table 53. Summary of gizzard shad catch by age-groups in the vicinity of the J. H. Campbell Power Plant, eastern Lake Michigan, 1977-1980. Gizzard shad were assigned to age-groups based on Bodola (1966). ND=no data.

Year	Age-Group	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1977	YOY	ND	ND				35	12	3	
	yearling and adult	ND	ND		3	14	15	1	91	
1978	YOY						16	10		32
	yearling and adult				1	65	42	5	18	
1979	YOY						2	10	1	2
	yearling and adult	3	1	1	1	2	0	11	1	
1980	YOY					28		21		
	yearling and adult			1	22	23	6	4	4	

Michigan at this contour. It is quite possible that under certain conditions these gizzard shad larvae, which came from the discharge canal, could be entrained by the 11-m depth intake structure at a later time or live and complete their life cycle in Lake Michigan.

Chinook Salmon

Chinook salmon catches during our study have increased steadily from 4 in 1977 to 32 in 1978, 67 in 1979 and 99 in 1980. During the last 3 yr, collections were dominated by recently smolted fish. Smolts comprised from 66 to 75% of the catch between 1978 and 1980. However, chinook spring fingerlings stocked by the Michigan Department of Natural Resources have decreased (from 700,192 in 1978 to 500,200 in 1980) in counties immediate to our sampling area (i.e., Ottawa, Allegan and Newago), so our progressively greater catches are not easily explained. It is possible that natural reproduction by chinook near our study site has increased during the last few years, since more fish with well developed and spent gonads were caught in 1979 and 1980 than in previous years. Mature males (18 total) have consistently outnumbered mature females (9 total) in our samples.

In general, chinook were present in our sampling area from April through November in water temperatures from 5 to 21 C. Jack salmon (200-420 mm) usually were gillnetted in spring, while smolts (70-120 mm) were seined in beach zones mostly during June and July. Adult chinook migrate from deep

water to spawn and mature salmon (up to 1010 mm) were most commonly captured in gill nets from September through November. Chinook were taken at all sampling depths (beach-12 m). Night catches surpassed day catches in earlier sampling years, but diel catch differences were not observed in later years. No consistent differences were noted between chinook catches at north and south transects.

Coho Salmon

During 1977-1980, 18 to 75 coho salmon were caught per year in the study area. Coho salmon collected ranged from 41 to 850 mm, most being small individuals <200 mm (Appendixes 7, 27, 28 and 29). Patriarche (1980) reported that 9.3% of coho salmon caught in Lake Michigan during 1979 were naturally spawned. Coho salmon planted in the spring were 100-152 mm (M. Patriarche, personal communication, Institute for Fisheries Research, Michigan Department of Natural Resources, Ann Arbor, Mich.). Juvenile coho salmon 41-99 mm, which occurred in small numbers in the study area during 1977-1979, probably originated from natural reproduction. In the spring of 1978 all coho salmon planted by the four states bordering Lake Michigan were marked by fin clips. Seven fin-clipped coho were caught in 1978 and six in 1979. Of these 13 marked fish, seven came from the Grand or Muskegon Rivers, two from Little Manistee River, two from the St. Joseph River, one from the Platte River and one from Indiana.

Coho salmon 41-190 mm occurred from May to October, with most being found during May, June and July (Appendixes 7, 27, 28 and 29). Most of these smaller coho salmon (96%) occurred in night beach seines. These data agreed with Tody and Tanner (1966) who reported young coho salmon remained close to shore upon first entering the sea. Small coho salmon moved offshore during summer; a few were caught in bottom gill nets at 6 and 9 m during July, August and September.

Larger coho salmon 240-820 mm migrate inshore during spring and fall. Most were collected in night bottom gill nets. Approximately 25% of larger coho salmon were caught during April and May; most were found during September, October and November. A few larger coho salmon were also collected during June and July 1978. A few coho salmon collected during fall were from 240 to 410 mm. Based on age-length data for coho salmon collected in Lake Michigan during the fall (Patriarche 1980), these coho salmon were 2-yr old. Most coho salmon collected during fall were adults (420-820 mm), several of which showed well developed gonads. Coho salmon migrate upstream to spawn. Jude et al. (1981a) found adult coho salmon in Pigeon River during the spawning season and suspected that some spawning could occur in this tributary stream. Small coho salmon (41-190 mm) were found in relatively warm water (11-21 C). Most larger coho (300-820 mm) occurred in water temperatures of 5-13 C. These data agreed with Tody (1973) who reported coho salmon preferred temperatures around 11.6 C. Several adult coho, however, were caught in water temperatures of 18.5-23 C during September 1978. During 1980, 50% of larger coho salmon were found in water temperatures of 5-9 C and 50% in water temperatures 15-17 C.

Catches of larger coho salmon (>200 mm) at north and south transects were similar during the 4-yr period. Smaller coho (<200 mm) were more common at beach station Q or R (plant transect) than at beach station P (reference transect) in 1978. During 1980 more small coho were seined at the south reference transect than at north transect stations Q or R. Reasons for these catch differences are not known. Seine catches of small salmon at the two transects were similar during 1979.

Lake Whitefish

Introduction--

The lake whitefish is widely distributed in the fresh waters of North America, especially in large lakes and rivers. It is an important commercial species. Populations in Lake Michigan have been reduced in recent years due to environmental deterioration and depletion of stocks (Scott and Crossman 1973). Lake whitefish tend to inhabit deep waters in the Great Lakes. Van Oosten et al. (1946) found them most numerous at depths exceeding 25 m in Lakes Huron and Michigan. Thus most lake whitefish in the Campbell Plant vicinity have probably been outside the range of our sampling stations.

During our study there has been an increase in the number of lake whitefish collected. In 1977 and 1978, 11 and 9 were captured respectively; however, in 1979, 27 were collected, and 75 were taken in 1980. This trend was not observed in studies at the D. C. Cook Plant, where lake whitefish catch remained low from 1973 to 1980.

Lake whitefish usually inhabit shoal areas in spring, deep water in summer, and return to the shallows in fall to spawn (Scott and Crossman 1973). They usually spawn in November through December at water temperatures between 0.5 and 10 C, over silt-free substrates such as rocks, gravel or sand (Machniak 1975). In the Ludington area, whitefish spawn in October and November on a rocky reef (Liston et al. 1981). Larval Coregoninae are difficult to identify to species. Some of the coregonine larvae collected during our study may be lake whitefish (see RESULTS AND DISCUSSION, Unidentified Coregoninae, Larvae). They were taken so infrequently that the Campbell Plant vicinity is probably not an important spawning area for lake whitefish. No YOY lake whitefish were collected during our study.

Yearlings--

Great variation exists in growth rates of lake whitefish in various populations. In northern Lake Michigan Roelofs (1958) found age-1 lake whitefish varied from 108 to 171 mm. Two areas in Lake Superior yielded age-1 fish 180 - 200 mm (Dryer 1963), and Lake Erie age-1 whitefish were 165-180 mm (calculated length) (Van Oosten and Hile 1949). From these data, lake whitefish less than about 170 mm TL at the beginning of the growing season were assumed to be yearlings. Only a few were collected. In 1979 and 1980 three yearlings were taken in April, July and November at stations 6 m and deeper. All three were captured at relatively cold water temperatures, 4.7-5.5 C.

Adults--

Lake whitefish were collected from April to November during our study, most frequently in summer months. In 1977 and 1979 lake whitefish were most abundant in June and July. In 1978 their occurrence was scattered from April to August, and in 1980 they were most abundant in June, August and September (Appendix 7). Inshore-offshore movement was not traceable due to generally low abundance of lake whitefish. Scarcity of whitefish during fall, and complete absence of ripe-running or spent fish from study area collections, indicate that lake whitefish spawn elsewhere. Few fish were collected that had more than moderate gonad development. Somewhat more males (60) than females (35) were collected. Lake whitefish sex ratios usually approximate 1:1; however, males and females do not appear at the spawning grounds simultaneously, so uneven ratios are often observed (Machniak 1975).

Only one lake whitefish was captured in less than 3 m of water: in June 1980 a 222-mm fish, probably 2-yr old, was seined at beach station Q (south discharge). Most lake whitefish were collected in bottom gill nets during our study (85 fish), while 35 were trawled and 1 was taken in a surface gill net. Station E (12 m, south) exhibited the highest catch and was the deepest gill net station. However, trawl catches of lake whitefish at stations E and F (12 and 15 m, south) were similar, so peak abundance at station E may be a function of our sampling scheme. As in other studies (Van Oosten et al. 1946; Machniak 1975), lake whitefish may be found offshore from the Campbell Plant in deeper water.

Lake whitefish collected ranged from 142 to 700 mm TL. The majority of these were >390 mm, by which length most lake whitefish are sexually mature (Van Oosten 1939). Collection of lake whitefish occurred at water temperatures from 3.3 to 19.3 C. Temperature preference from our data appeared to be 7 to 15 C. Nearly all lake whitefish collected were taken at night.

Lake whitefish are primarily bottom feeders, consuming benthic macroinvertebrates and small fishes (Scott and Crossman 1973). Stomach contents of whitefish we collected included chironomid larvae, amphipods and gastropods. One lake whitefish 175 mm TL was infected with an acanthocephalan.

Plant Effects--

During most of our study, catches of lake whitefish were too low to draw any conclusions about plant effects. However, in August 1980, 23 whitefish were taken in bottom gill nets at station N (9 m, north), while only 5 were caught at station D (9 m, south). Water temperatures were similar: 14.0 C at station D and 15.0 C at station N. It is unlikely that lake whitefish would be attracted to the thermal plume, since they were usually found at temperatures below 15 C in our study, indicating a preference for cool water. Since increased catch at the north transect occurred only once, it is probably

not an important plant effect. Also, lack of adult fish sampling at 12- and 15-m north transect stations prevents us from comparing whitefish abundance at these preferred depths.

Brown Trout

Brown trout were first introduced to Lake Michigan in 1883 (Brynildson et al. 1973). Natural reproduction, occurring both in the lake and in inflowing streams, and subsequent plantings of several hundred thousand fish have resulted in the firm establishment of this species in the Lake Michigan basin (Becker 1976). Movements of brown trout can be fairly extensive. One year after being planted in Lake Michigan, some specimens were found up to 323 km from the point at which they had been released, though most recovered fish were found less than 24 km away (Becker 1976).

Variable numbers of brown trout were collected during the course of our study. Yearly catches were 49, 114, 88 and 50 fish respectively from 1977 to 1980. During all 4 yr, juvenile brown trout (106-200 mm) were caught predominantly in the beach zone where warmest water temperatures existed. Brown trout were captured at a wide range of water temperatures (3-21 C), but most fish were caught in water between 6 and 15 C. Larger fish (up to 707 mm) were generally found in water less than or equal to 6 m.

Brown trout are largely piscivorous (Brynildson et al. 1973). Stomach content data from our study indicated that brown trout fed heavily upon slimy sculpins and smelt during spring, and upon alewives during summer.

Although brown trout were generally present in our sampling area from April through November, greatest numerical catches of trout occurred during spring and fall. Fish probably move into sampling depths to feed during spring, then move back out to cooler water in summer. Diel movements by brown trout were also noted; more fish were caught at night than during the day. Many brown trout captured during fall had well developed gonads. Brown trout spawn in the fall when water temperatures are between 6.7 and 8.9 C (Scott and Crossman 1973).

Brown trout were more prevalent in south transect reference samples than in north transect samples. Differences were due to deployment of gill nets at 1.5 and 3 m (where many brown trout were collected) in the south while these contours were not sampled in the north. Gill nets were the most effective gear for catching brown trout during all sampling years.

Rainbow Trout

Rainbow trout were first introduced into the Lake Michigan watershed in 1880 (Smiley 1881) and by 1906 the population supported a commercial fishery with fish averaging about 0.45 kg in weight (MacCrimmon and Gots 1972). The next 20 yr would see a commercial fishery thriving on stocks thought to be sustained primarily by natural recruitment of anadromous fish spawning exclusively in Michigan streams. Coincident with the arrival in 1936 of the sea lamprey, numbers of rainbow trout declined and continued to do so through

the 1940s and 1950s. As efforts to control sea lamprey (initiated in 1948) were intensified for Lake Michigan tributaries during the early 1960s, greater numbers of rainbow trout were stocked. In 1966 254,000 rainbows were planted in Lake Michigan tributaries and by 1973 the total annual planting had risen to over 3 million. Since 1973 annual plantings have ranged from 1.3 to 1.9 million fish.

During 1980, 26 rainbow trout (270-840 mm) were collected in the vicinity of the Campbell Plant (Appendix 7) as compared to previous catches of 29, 9 and 8 in 1979, 1978 and 1977 respectively (Jude et al. 1980, 1979a, 1978). The substantial rise from 1978 to 1979 might be attributable to an increase in the number of rainbow plantings in Pigeon Lake from 5,038 in 1975 to 20,275 in 1976 and 10,000 in 1977 (Great Lakes Fish Commission 1978, 1979, 1980). Stocked as 2- to 3-yr olds, these fish should have matured by age 5, and returned to our study area within 3 yr (1978, 1979, 1980). Two of the 26 rainbows collected in 1980 were caught in the spring. One was captured in a bottom gill net at station A (1.5 m, south), and the other was seined in May at beach station P (south reference). The remaining 24 fish were caught with increasing frequency from late summer to late fall. Most rainbows were found at 6-m depths or less and all were gillnetted, with surface outnumbering bottom net catches 44 to 10. Water temperatures at time of capture ranged from 3 to 17 C. Over the 4-yr study period, 90% of the rainbow trout were collected at night, indicating diel inshore and offshore movements.

During 1979 rainbow trout were most abundant in the spring when 17 fish were collected in April. One rainbow was gillnetted in May and the remainder were taken in October (five) and November (five). Of the nine rainbow trout captured in 1978, four were collected in the spring and five in the fall. Sampling began in June 1977; consequently, all rainbows collected that year were caught in the fall.

Populations of both spring- and fall-spawning rainbow trout have been planted in Lake Michigan (Daly et al. 1975). Gonad data suggest that individuals of both stocks have been encountered in our study area. Fifty percent of the fall 1980 catch was found to have well developed gonads; whereas, spring spawners prevailed in 1979 (Jude et al. 1980). Few rainbows were collected in 1978 and 1977; however, sexually mature individuals were present in September and November samples.

Supplementary sampling and visual observation indicate that adult rainbow trout were utilizing the discharge canal during winter 1979 and spring 1980 (Jude et al. 1980). Stomach analysis of these fish revealed an abundance of gizzard shad and alewives, presumably consumed while in the canal. Seasonal high densities of forage fishes near thermal discharges into Lake Michigan (Romberg et al. 1974) could attract salmonid fish and may provide energetic advantage to plume residents.

Golden Shiner

Golden shiners were collected from Lake Michigan only in 1980 in our study. They prefer weedy, quiet water with extensive shallow areas (Scott and Crossman 1973). They are common in Pigeon Lake, particularly areas influenced by the Pigeon River (Jude et al. 1981a). It is likely that those golden shiners observed in Lake Michigan originated from Pigeon Lake. Seine hauls at beach stations P (south reference) and Q (south discharge) in October 1980 yielded 15 golden shiners. Eleven of these were immatures from 37 to 53 mm, probably YOY. They were collected during the day and night at water temperatures of 10.5-11.0 C. The four remaining shiners were 84-90 mm, all adults. These four were collected during the day at beach stations P and Q along with the YOY. Three were females with slight to moderate gonad development and one was in such poor condition that sex could not be determined. No golden shiner larvae were collected from Lake Michigan during our study.

Common Carp

Introduction--

The common carp, a native of eastern Asia, was widely introduced in North America in the late 1800s. It has become abundant in many locations, particularly where both shallow marsh habitat for spawning and deeper water for overwintering are available (McCrimmon 1968). These requirements are met in our study area. Pigeon Lake is bordered by several small marshes and deeper water for overwintering is provided by both Pigeon Lake and Lake Michigan.

Adult carp were occasionally collected during our study. In 1977, 7 were captured; in 1978, 13; in 1979, 10; and in 1980, 14. Percentage of carp in the total catch was about 0.01% in each of the 4 yr. Carp also comprised about 0.01% of the catch in studies at the D. C. Cook Nuclear Plant (Jude et al. 1979b). Carp are common in warm waters (Becker 1976) and are more abundant in inland waters than in Lake Michigan.

Larval carp were collected more frequently than would be expected from the occurrence of adults. Spring spawning presumably occurs inland, not in Lake Michigan, due to cold water temperatures. However, spawning has occurred regularly in Lake Michigan at the Cook Plant after startup of Unit 1, presumably due to the warm-water discharge (Jude et al. 1979b). Swee and McCrimmon (1966) reported that spawning did not occur below 17 C in Lake St. Lawrence, and optimum spawning temperatures were between 19 and 23 C. Water temperatures above 19 C did not occur in Lake Michigan until at least early July in our study, yet carp larvae were collected in May 1979 and in mid-June 1980. Later spawning may occur in Lake Michigan, but preferred spawning habitat is not present; therefore lake spawning is probably less successful.

Populations of carp exist in Pigeon Lake and the intake and discharge canals of the Campbell Plant (Jude et al. 1979a). The warm water of the discharge canal is conducive to early spawning, although little vegetation was present even before construction of Unit 3 began. Carp larvae captured early in the year in Lake Michigan may have been produced by the discharge canal population. Reproductive contributions of carp populations in Pigeon Lake and the intake and discharge canals occur at different times, explaining the capture of larvae at widely separated times throughout the year.

Larvae--

First occurrence of carp larvae in Lake Michigan was in mid-May to June during the study. These larvae were thought to be from intake or discharge canal spawning in 1979 and 1980, while in 1978 they probably originated from Pigeon Lake. These conclusions are based on samples in the intake canal, Pigeon Lake and entrainment samples from Units 1 and 2. Densities of larval carp collected in Lake Michigan in May and June were somewhat higher at the north plant transect compared with the south transect. For example, in May 1979 carp larvae were collected at north transect stations Q (beach, south discharge), I (1.5 m, north), J (3 m, north), L (6 m, north) and O (12 m, north), with estimated densities of 15 to 195 larvae/1000 m^3. At the south reference transect carp larvae were captured only at stations P (beach, south reference) and B (3 m, south) with estimated densities of 21 and 63 larvae/1000 m^3 respectively (Fig. 90). These differences are evidence for intake or discharge canal spawning. Similarly, Waybrant and Shauver (1979) found much higher densities of carp larvae in backwater or vegetated areas compared with open waters of Lake Erie. Carp larvae in their study area were captured relatively close to the mouth of the Huron River, which was probably the source of carp larvae rather than Lake Erie.

In the 4 yr of the study, carp larvae were always collected during July except in 1979. August and September catches included some larval carp in 1979 and 1980 respectively (Fig. 90). The discontinuous, apparently sporadic occurrence of carp larvae can be attributed to spawning of separate populations.

Carp larvae were collected at water temperatures from 9.5 to 24.2 C. Although larval carp were captured from the beach to 15-m stations, they were more abundant inshore (Fig. 90) and remained above the thermocline when in deeper water (never deeper than the 8.5-m stratum). Densities of carp larvae in Lake Michigan during the study ranged from 15 to 591 larvae/1000 m^3, with greatest densities occurring at beach stations and the 1.5-m contour. These values compare with densities of 1 to 103 larvae/1000 m^3 obtained by Cole (1978) from Lake Erie.

Carp larvae collected during our study were mostly between 4.0 and 7.0 mm TL and were recently hatched. The largest carp larva, 10.5 mm, was taken 28 July 1977 at station I (1.5 m, north) at a water temperature of 11.8 C. Larger larvae were captured infrequently, perhaps due to mortality or net

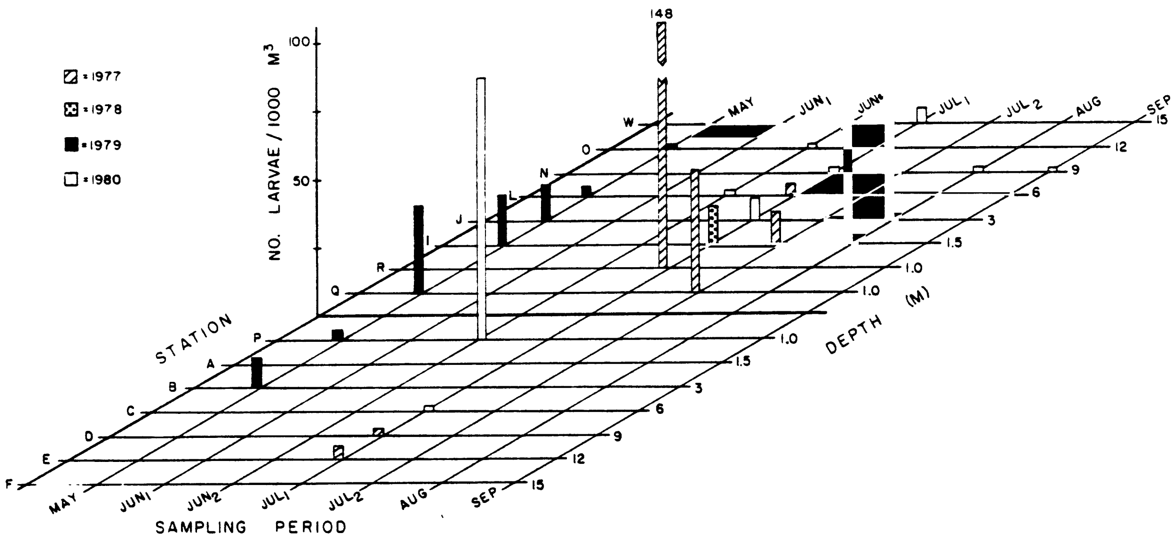


Fig. 90. Mean density (no./1000 m³) of larval carp for north and south transect stations in Lake Michigan near the J. H. Campbell Plant, 1977 to 1980. Mean densities were calculated by averaging densities over all gear (plankton nets and sleds), strata and diel periods (day and night).

avoidance, so a pattern of length distribution with depth could not be detected. Carp larvae were captured in both day and night samples; no diel pattern was apparent.

No YOY or yearling carp were collected in Lake Michigan during our study. Absence of age-groups of carp between larvae and adult suggests that Lake Michigan near the Campbell Plant does not serve as a favorable nursery area. Absence of YOY at any time during the study further suggests that those larvae spawned in Lake Michigan or those which drifted from inland sources, do not survive. It is likely, therefore, that adult carp captured in Lake Michigan near the Campbell Plant were spawned and reared in inland waters connected to Lake Michigan, which are more conducive to spawning and successful rearing of carp. Some of these carp then disperse from their rearing areas into Lake Michigan as adults. The nearest successful rearing area to the Campbell Plant is Pigeon Lake as indicated by observations of YOY there in 1977 and 1978 (Jude et al. 1979a). In Lake St. Lawrence, YOY carp were found in shallow marshes until at least mid-autumn (Swee and McCrimmon 1966).

Adults--

Seasonal distribution of adult carp in Lake Michigan near the Campbell Plant showed no obvious trends. A slight movement offshore from spring to fall was suggested, since in April carp were collected only from beach stations to 6 m, while in late summer and fall carp were sometimes collected at stations E (12 m, south) or F (15 m, south). Throughout the year, however, carp were most frequently found nearshore (to 6 m). In 1978 peak catch of

carp occurred in August; however, in other years the catch of adult carp remained relatively constant from April to October or November. None were collected in December of any year.

Adult carp in our samples ranged in length from 515 to 780 mm. They were most effectively sampled by bottom gill net (29 fish); however, some carp were also collected by seine (10 fish) and trawl (5 fish). More carp were found in night samples than day samples. Carp were collected at water temperatures from 3.9 to 24 C, but the greatest catch occurred at temperatures from 8 to 17 C.

Carp with well developed gonads were observed from April to November in the study area; however, the only ripe-running fish was a male in July 1980. Occurrence of carp with well developed gonads from spring to fall may be due to repeated spawning by individuals, or spawning at widely differing times. In the vicinity of the D. C. Cook Nuclear Plant, carp with well developed or ripe gonads were observed May through July (Jude et al. 1979b). During our study somewhat more females (24) than males (20) were collected.

Plant Effects--

From 1977 to 1979 adult carp showed no particular trend in catch difference between reference and plant transects. In 1980, however, catch of carp (five fish) was greatest at station N (9 m, north); two were the most collected at any other single station. Temperature preferences of carp are known to be above 25 C (Reutter and Herdendorf 1974). Pitt et al. (1956) found final preferred temperature to be 32 C for YOY carp. Carp may therefore be attracted to the vicinity of the thermal plume emitted by the Campbell Plant. However, so few adult carp were caught that their attraction to the warm-water plume cannot be confirmed at this site.

In the vicinity of the D. C. Cook Plant near Bridgman, Michigan, occurrence of carp larvae at plant transect stations indicated carp spawning in the thermal plume (Jude et al. 1979b). This may occur at the Campbell Plant as well, although spawning in the intake and discharge canal is thought to be more important. The Wilcoxon signed ranks test showed that for 27 cases during the 4 yr, there was a tendency for carp larvae to be more abundant at the north transect than at the south reference transect (significant at $\alpha = 0.05$).

The Campbell Plant has provided favorable habitat for carp spawning in the intake and discharge canals. More sheltered and warmer than Lake Michigan, the canals provide optimal water temperature, food and habitat for early spawning. Larvae produced there may survive and contribute to carp populations in Pigeon Lake and Lake Michigan.

<u>Silver Redhorse</u>

The silver redhorse is uncommon in the Lake Michigan basin, and primarily inhabits moderate to large rivers and reservoirs (Becker 1976). Like other redhorses, it was collected infrequently in the Campbell Plant vicinity.

Twelve were captured in 1977; 4 in 1978; 3 in 1979; and 14 in 1980. One juvenile (57 mm) and three adults were caught in a July, 1977 night seine haul at beach station R (north discharge). All other silver redhorses collected were adults taken in bottom gill nets. Water temperatures at time of collection ranged from 8 to 24 C; most fish were caught at 12 to 20 C. Adult fish ranged in length from 365 to 595 mm.

Silver redhorses were captured from June to November from the 1- to 6-m depth contours. Most were collected in late summer through fall. More were collected at night than in daylight. No trends between reference and plant transects were apparent.

Eighteen male and 13 female silver redhorses were collected. Well developed gonads were observed from July through September; no ripe-running or spent fish were captured, so spawning time is unknown for our study area.

<u>Channel Catfish</u>

Although the catch of channel catfish in any year did not exceed 10 fish, our data indicate that during August and September channel catfish exhibit a migration to some extent into Lake Michigan, possibly from large river systems. With the exception of one channel catfish caught in April 1980, all occurrences of channel catfish in Lake Michigan samples were observed from August to October. Since channel catfish are not common in Pigeon Lake, it is possible that those individuals caught in Lake Michigan originated from Lake Macatawa (15 km south of the plant) or the Grand River (17 km north of the plant). While it is possible that the intake and discharge riprap may be an attractive influence for channel catfish as was suggested to occur at the Cook Nuclear Power Plant (Jude et al. 1979b), it is doubtful that plant operation will cause any impact on channel catfish populations in adjacent areas.

One YOY channel catfish (60-mm length interval) was trawled at station D (9 m, south) in December 1979. The remaining channel catfish collected were mature adults, 285-734 mm in length, including 18 males and 7 females. All had slightly or moderately developed gonads, another indication that they do not spawn in Lake Michigan in our study area. Adults were taken in bottom or surface gill nets, mostly at depths of 6 m or less. Channel catfish appeared to prefer warm (>15 C) water temperatures. Most were collected at night.

<u>Shorthead Redhorse</u>

The shorthead redhorse occupies a wider range of habitats than other species of <u>Moxostoma</u>, being present in lakes and in moderate to large streams (Becker 1976). Shorthead redhorses are uncommon in the vicinity of the Campbell Plant; from 1977 to 1980, only 13 adults were collected. No larvae, YOY or yearlings were observed during the study. In 1980 seven were captured, which was more than in any previous year. During the study all redhorses were taken in bottom gill nets, mostly at night. Water temperatures at time of capture ranged from 10 to 21 C. Fish collected were between 340 and 700 mm in length.

Shorthead redhorses were collected from June to October, most frequently at station A (1.5 m, south), but a few were caught at 6- and 9-m stations. There were no apparent differences in catch between reference and plant transects.

More females (eight) than males (four) were collected during the 4 yr. Most had slight to moderate gonad development; individuals with well developed gonads were observed twice, in August and October. One spent female was collected in June 1979, indicating spawning during spring.

Burbot

Introduction--

The burbot is widely distributed in North America and Eurasia in deep waters of lakes and large, cool rivers. It prefers water temperatures 15.6 to 18.3 C and spawns in midwinter, under the ice, in shallow water (Scott and Crossman 1973). At the Campbell Plant adult burbot are infrequently collected because they inhabit deep water during our sampling season and move inshore to spawn in winter, when sampling is not conducted. Because of inshore spawning, burbot larvae have been collected more often than adults. Adult burbot have been observed in Pigeon Lake in December and February, and larval burbot have appeared in Pigeon Lake and in entrainment samples from Units 1 and 2. Therefore, Pigeon Lake, in addition to Lake Michigan, is a likely spawning site for burbot.

Larvae--

Burbot larvae first appeared in Unit 1 and 2 entrainment samples on 11 April 1978. Field larvae samples from Lake Michigan usually contained burbot larvae from mid-April to mid-June. Many newly hatched (3.6 to 5.0 mm) larvae occurred in samples from April through June.

Seasonal distribution varied from year to year. In 1977 no burbot larvae were collected, probably because sampling commenced in June. In 1978 burbot larvae were most abundant in April at the north transect, particularly at beach stations R and Q. Estimated densities in the nearshore zone ranged up to 564 larvae/1000 m^3. High densities at beach stations indicated spawning may have taken place there.

In 1979 no larval burbot were collected in April, but some were taken in May and more in June. Unlike other years, burbot larvae occurred at mid-depths and not at beach stations. Estimated densities were low, 16 to 48 larvae/1000 m^3. Perhaps hatching occurred after our April sampling and larvae had begun to disperse by May.

In 1980 burbot larvae were most abundant during May at beach stations R (north discharge) and P (south reference), at densities as high as 843 larvae/1000 m^3. Larvae were less abundant in deeper water, but they were found from 1 to 15 m at the north transect and 1 to 12 m at the south transect, which was similar to the April 1978 distribution. Our data suggest

spawning near the beach and subsequent dispersal of larvae to deeper waters. Larger larvae (to 7.5 mm) were generally found in 6-15 m of water; this was the only trend in distribution by size. A later peak of abundance in 1980 than 1978 suggests later hatching.

Burbot larvae usually were slightly more abundant at or near the bottom than in surface tows. More larvae were found in night samples than day samples, particularly larger larvae, to 7.5 mm. Burbot larvae were collected at water temperatures from 4.5 to 16.0 C, however, most newly hatched larvae were taken at cooler temperatures, from 4.5 to 10 C.

Young-of-the-Year and Yearlings--

Burbot undergo rapid growth, especially in their first year (Muth 1973; Scott and Crossman 1973). Three immature burbot 95-144 mm trawled in late summer and fall 1978 were probably YOY. All were collected at station E (12 m, south); water temperatures were 10 to 14 C. One male burbot with slightly developed gonads was trawled in October 1978 from station C (6 m, south); it was in the 160-mm length interval and was probably a yearling. All four of these fish were collected at night.

Adults--

Few adult burbot were collected during our study, due to their preference for deep water. In December 1977 a female with well developed gonads was trawled at station D (9 m, south). No mature burbot were collected in 1978 or 1979. Five burbot, all females, were collected in 1980 by bottom gill net and trawl at stations 3 to 9 m in depth. One, collected in April, was spent; the others, taken during October and November, exhibited moderately to well developed gonads. Most adult burbot were collected at night. Water temperatures at time of capture were 1 to 12 C. The six fish ranged from 319 to 618 mm. Stomach contents of several burbot examined included alewives, rainbow smelt, gizzard shad and sculpins.

Plant Effects--

Although in 1978 burbot larvae were more abundant at the north transect than the reference transect, a Wilcoxon signed ranks test showed this was not statistically significant at $\alpha = 0.05$. Larvae were evenly distributed between transects in 1979 and 1980. Adult burbot exhibited no particular difference in abundance by transect. Preliminary SCUBA observations did indicate that burbot were attracted to the intake and discharge areas, presumably due to the increased cover afforded by the riprap.

Mottled Sculpin

During preoperational years 1977-1980, the mottled sculpin only occasionally occurred in Lake Michigan near the Campbell Plant. Only four mottled sculpins were caught during 1977, while one was caught in 1979 and five were taken in 1980. Mottled sculpins were not collected in Lake Michigan near the Campbell Plant in 1978.

Mottled sculpins were collected only by trawling, mostly at night, during our study. They were taken at stations 9 m or deeper, at water temperatures from 4 to 14 C. Sculpins ranged in size from 25 to 94 mm; adults had only slight gonad development.

While the typical habitat of mottled sculpin does not include the open water area of Lake Michigan, construction of artificial reefs in the inshore zone has often resulted in the establishment of local populations there, similar to what occurred at the D.C. Cook Plant (Jude et al. 1979b). It is likely that a similar situation will develop at the Campbell Plant structures as mottled sculpins from adjacent Pigeon River occasionally disperse into Lake Michigan, take refuge in and colonize the riprap area. Mottled sculpins will probably remain in the intake area throughout the summer months when slimy sculpins exhibit an offshore distribution (see RESULTS AND DISCUSSION, Slimy Sculpin), and may gain importance as forage for some of the warm-water species of fish (i.e., yellow perch).

Golden Redhorse

The golden redhorse usually inhabits streams (Becker 1976); it was uncommon in the Campbell Plant vicinity during our study. In our 1977 sampling none were captured in Lake Michigan; in 1978, 4; in 1979, 10; and in 1980, 4. No golden redhorse larvae, YOY or yearlings were collected. All fish collected in Lake Michigan were caught in bottom gill nets at water temperatures from 8 to 22 C. Lengths ranged from 400 to 636 mm.

Golden redhorses were caught during June to October from the 1.5- to 6-m depths, somewhat more frequently at shallower depths. Unlike other suckers, golden redhorses were not collected in greater numbers at night than in daylight. No trends in catches between reference and north transects were apparent.

Ten male and eight female golden redhorses were collected; most had slight to moderate gonad development. In July 1979 three fish with spent gonads and two females with reabsorbing eggs were caught, which indicates some spawning occurred before 17 July.

Longnose Dace

Longnose dace are found in swiftly flowing streams, lakes and inshore waters of the Great Lakes (Scott and Crossman 1973). Although they are widely distributed, they are uncommon in our study area. Apparently the beach zone near Ludington, north of the Campbell Plant, provides more favorable habitat as Anderson and Brazo (1978) seined dace in sizable numbers during 1975.

Three dace were collected in 1977 and three in 1980 during our study. Their benthic habit should make them susceptible to trawling, but only one was captured in our trawls, probably because of their preference for the beach zone. No longnose dace larvae were collected. Two fish 45-54 mm seined in November 1977 at beach stations P (south reference) and Q (south discharge) were probably YOY. A 49-mm longnose dace seined in July 1980 at station Q was

probably a yearling; it had undeveloped gonads. Two adult longnose dace, 55-105 mm, were seined in October 1977 and July 1980 respectively, at beach station P. One was a spent female and one a male with slight gonad development. The only fish captured by trawl was 82 mm, taken in July 1980 at station C (6 m, south). Longnose dace were collected at water temperatures from 10 to 21.5 C. Most were captured at night. It is unlikely that plant operation will affect this species, since it is uncommon in the Campbell Plant vicinity.

Walleye

Walleyes are planted in the Muskegon River system (47 km north of the Campbell Plant) and in Lake Macatawa (19 km south of the Campbell Plant). Walleyes also spawn naturally in eastern Lake Michigan (R. Lincoln, personal communication, Mich. Dept. Nat. Res., Grand Rapids, Mich.). However, walleyes are uncommon in Lake Michigan in the vicinity of the J. H. Campbell Plant.

No walleyes were observed in Lake Michigan field samples in either 1977 or 1979. In 1978, seven YOY walleyes were collected, six in beach seines in August when water temperature was between 22 and 25.7 C and one in a trawl haul at 6 m in December when water temperature was 1.0 C. Whether these fish migrated from their planting site or originated from natural reproduction is not known.

Three walleyes between 415 and 444 mm were gillnetted in fall 1980 at water temperatures between 9 and 11 C. All three fish were males with moderate to well developed gonads. These fish were all caught from the north transect and may have been attracted to the riprap in the area. Becker (1976) reports that walleyes prefer clear water with gravel, rock, sand or hard-clay bottoms. It is possible that greater numbers of walleyes will concentrate around the Campbell riprap in future years, since several species which serve as forage fish for walleye (e.g., alewife, trout-perch, rainbow smelt and yellow perch) may also concentrate near the riprap.

Central Mudminnow

The central mudminnow inhabits small creeks and isolated ponds (Scott and Crossman 1973). Its presence has been noted in small creek tributaries of the Pigeon River within about 12 km of the J. H. Campbell Plant (Jude et al. 1981a), and one specimen was caught in Pigeon Lake in May 1978 (Jude et al. 1979a). The collection of an immature mudminnow and a male with well developed gonads in Lake Michigan (12 m, south) in May 1980 was therefore considered unusual.

Several mudminnows (many with ripe-running or well developed gonads) have been collected from traveling screens at the D. C. Cook Plant, southeastern Lake Michigan, always during spring (Jude et al. 1979b). Central mudminnows spawn in mid- to late April (Scott and Crossman 1973) so their presence in Lake Michigan may be related to spawning behavior.

Yellow Bullhead

Only two yellow bullheads were caught in Lake Michigan during the entire study period. They were collected at stations B (3 m, south) and L (6 m, north). Both fell in the 180-mm length interval. Their occurrence in July 1980 suggests that they only rarely enter Lake Michigan, and thus have little ecological importance in this system.

Quillback

Populations of quillbacks inhabit the Grand and Macatawa rivers (Becker 1976); from these sites north and south of the Campbell Plant this species may spread to the plant vicinity. Quillbacks were observed in our Lake Michigan samples in 1978 (two) and 1980 (four). An 8.2-mm quillback larva was collected at night on 27 April, 1978 at beach station Q (south discharge). The calculated density was 282 quillback larvae/1000 m^3. This larva may have originated from spawning in the discharge canal, since quillbacks have been observed there.

Adult quillbacks were occasionally caught during our studies from June to October and during studies at the D. C. Cook Plant (Jude et al. 1979b). They were collected most frequently in bottom gill nets at 1.5- and 3-m depth contours in both studies. One individual at the Campbell Plant was captured in a seine haul in June, 1978 at beach station Q (south discharge). All quillbacks were collected at night when water temperatures were 10 to 24 C. These fish ranged in size from 415 to 504 mm and included two males and four females. None had ripe-running or spent gonads. There were no apparent differences in catch between reference and plant transects.

Deepwater Sculpin

Introduction--

Prior to 1980, some confusion over the taxonomy of fourhorn/deepwater sculpins existed. Recent changes have been made, such that fourhorn sculpins (*Myoxocephalus quadricornis*) previously reported from the Great Lakes region were probably deepwater sculpins (*Myoxocephalus thompsoni* - Robins et al. 1980). Deepwater sculpins inhabit deep lakes of North America. Not much is known concerning the biology of this species because it is seldom found inshore (Scott and Crossman 1973). Jacoby (1953) determined deepwater sculpins in Lake Superior to be most abundant from 100 to 240 m; larger fish tended to inhabit deeper water. In Lake Michigan deepwater sculpins were distributed from approximately 50 to 200 m (Deason 1939). Previous studies have indicated spawning occurs in summer or early fall (Scott and Crossman 1973). For the closely related fourhorn sculpin (*Myoxocephalus quadricornis*), males guard nests until hatching; development took 55 to 100 days in the laboratory at temperatures below 5 C (Westin 1969). Larval sculpins from the Campbell Plant vicinity which were identified as fourhorn sculpins in 1978 and 1979, and reported in previous Special Reports, are now designated deepwater sculpin larvae because of this recent taxonomic change.

Larvae--

Deepwater sculpin larvae (9-10 mm) were first collected in early February entrainment samples. Eggs producing these larvae were probably spawned the previous November or December. Deepwater sculpin larvae were most abundant in field samples taken during April and May, occasionally appearing until mid-August. Estimated densities were low, 11 to 71 larvae/1000 m^3. Larvae as small as 9.5 mm were taken in July, indicating a prolonged spawning period or slow growth. Deepwater sculpin larvae were collected at water temperatures from 2.3 to 10.2 C, most below 8.0 C. Cool water temperatures and small maximum size of adults imply slow growth of larvae; thus it is difficult to infer spawning time from presence of larvae. In Lake Superior deepwater sculpins are believed to spawn from November to mid-May (J. H. Selgeby, personal communication, U. S. Fish and Wildlife Service, Ashland, Wisc.). Near Ludington deepwater sculpin larvae were present in collections from 17 April to August; however, highest densities were in April and May. Larvae collected during the summer were larger (13-22 mm) and occurred during upwellings of cooler water (Liston et al. 1981). These data in addition to our studies indicate spawning from early winter possibly to early spring in eastern Lake Michigan.

Deepwater sculpin larvae were collected at stations from 6 to 18 m in depth and at depth strata of 2.5 to 17 m. Larvae tended to be in the lower part of the water column. Although there was no month-by-month trend in abundance at various stations, absence of deepwater sculpin larvae during late summer and fall is probably due to offshore movement of YOY from our study area. Further evidence for this is the virtual absence from our trawl samples of YOY, yearling or adult deepwater sculpins.

Larval deepwater sculpins 9.0 to 18.3 mm were collected in field samples. Somewhat more larvae occurred in night samples than day samples.

Supplemental sampling in May 1981 at 80 and 100 m by M. Evans (Great Lakes Research Division) yielded a few deepwater sculpin larvae less than 10 mm. This indicates probable spawning offshore in addition to possible spawning at 6 to 15 m. Liston et al. (1981) found abundance of deepwater sculpin larvae increased with depth, to a sampling limit of 12.1 m. Larval deepwater sculpins occurring in our sampling area were most likely carried inshore by currents. Their pelagic existence as larvae makes them vulnerable to surface water movements. Also, adults are common in deep water (as shown by supplemental trawling at 80 and 100 m), but virtually absent from inshore waters. These two factors suggest offshore spawning and subsequent dispersal of pelagic larvae. Higher densities of sculpin larvae than those we found would probably result if significant spawning occurred inshore.

Yearlings and Adults--

A 22-mm deepwater sculpin was trawled at station N (9 m, north) in May 1980. This fish was somewhat larger than most larvae captured in May, suggesting it was spawned the previous summer. A 90-mm female with moderate

gonad development was trawled at station E (12 m, south) also in May 1980. Both fish were collected at night, at water temperatures 6.0 to 6.1 C. These were the only deepwater sculpins other than larvae collected during our study.

Supplemental trawling in May 1981 by M. Evans at 80 and 100 m captured several adult deepwater sculpins 111 to 143 mm in length. As was found by previous studies, deepwater sculpins prefer deeper water than we normally sample. Thus, deepwater sculpins are not subject to much impact by power plants except by occasional entrainment of larvae. Even larvae ranging inshore did not exhibit a difference in abundance between transects.

Black Crappie

Common residents of adjacent Pigeon Lake, adult black crappies rarely disperse into Lake Michigan near the Campbell Plant. In the 4-yr period, 1977-1980, only one adult black crappie was caught; it occurred at beach station P (south reference) in June 1980. Data indicate however that larval black crappies hatched from inland sources may drift into the adjacent Lake Michigan area. During May and June 1979, sporadic densities as high as 149 larvae/1000 m^3 were reported at beach station P (south reference) with decreased densities out to station F (15 m, south) (13 larvae/1000 m^3). Water temperatures when larvae were collected ranged from 9.0 to 16.5 C. The discharge canal, in which crappies have been observed spawning, may serve as a periodic source of black crappie larvae in the future.

Freshwater Drum

Freshwater drums are rare in the area of the Campbell Plant as only two specimens were collected at Lake Michigan stations, one (460 mm) in September 1978, and one (630 mm) in November 1980. Their occasional presence in impingement samples at Campbell Units 1 and 2, as well as Pigeon Lake (Jude et al. 1979a) indicate that there may be a small population in the Pigeon Lake area. As would be expected from the low density of adults, no larval drums were collected in the area of the plant. The species appears to have little ecological significance in the vicinity of the Campbell Plant.

Lake Herring

Lake herring, also known as cisco, occurred infrequently in our study area. One individual (153 mm) was collected in June 1980 during night trawling at station N (9 m, north). The only other appearance of this species over the 4-yr study occurred in August 1977 when a 389-mm female was gillnetted in Pigeon Lake (Jude et al. 1978).

Lake herring is a member of the subfamily Coregoninae which has shown a dramatic increase in abundance during the 4 yr of sampling (see RESULTS AND DISCUSSION, Unidentified Coregoninae). Difficulty in identifying species of the genus *Coregonus* allows for the possible inclusion of some lake herring (*Coregonus artedii*) into this large taxonomic group, although bloater (*Coregonus hoyi*) are believed to comprise the majority of unidentified Coregoninae collected in our study area.

Northern Pike

Northern pike is a common species in Pigeon Lake (Jude et al. 1978, 1979a, 1980, 1981a). They sometimes migrate into Lake Michigan, often moving alongshore for great distances. Northern pike tagged in Pigeon Lake have been recaptured as far south as Lake Macatawa (15 km south of Port Sheldon) and as far north as Muskegon Lake (37 km north of Port Sheldon). In Lake Michigan two northern pike were collected in 1978 and one was collected in 1980. They were gillnetted at south transect stations 1.5-6 m in depth, in August and October. These pike ranged in size from 255 to 774 mm. Their rare occurrence in Lake Michigan near the Campbell Plant suggests that Unit 3 operation will not have any adverse affect on this species, and that Units 1 and 2 are not affecting their distribution.

Bluegill

Bluegills were common in Pigeon Lake, but were rare in Lake Michigan near the J. H. Campbell Plant. Several YOY bluegills 25-50 mm were collected in Lake Michigan during 1977, 1978 and 1980. One yearling bluegill (84 mm) was caught in 1978. Most bluegills collected in Lake Michigan were seined at north transect stations R and Q during September and October (Appendixes 7, 27, 28 and 29). One YOY bluegill was trawled at 15 m at the south transect during September 1978 and one YOY occurred in a larval sled tow during September 1977. Water temperatures at time of capture ranged from 10.3 to 19.0 C. All bluegills collected in the Lake Michigan study areas probably originated from Pigeon Lake or the discharge canal.

Lepomis spp. larvae were collected at the north and south transects during 1977, 1979 and 1980 in densities varying from 48 to 267 larvae/1000 m^3 (Appendixes 9, 10, 33, 35, 36 and 39). Unidentified *Lepomis* spp. collected in the study area were probably bluegill or pumpkinseed larvae. Since no sunfish spawning occurred in Lake Michigan near the J. H. Campbell Plant, these *Lepomis* spp. larvae were probably carried to Lake Michigan via the discharge canal.

Lake Sturgeon

The lake sturgeon has suffered the most abrupt decline of any species in Lake Michigan (Wells and McLain 1973). This species is rare in the area of the Campbell Plant as only two were captured, one (584 mm) in July 1977 and one (795 mm) in May 1979 at stations Q (beach, south discharge) and L (6 m, north) respectively. Water temperatures were 21 and 13 C. It is doubtful whether plant operation will in any way effect a further demise of lake sturgeon.

Brook Silverside

Only one brook silverside was captured in Lake Michigan during the study period (October, 1977 at south reference beach station P). Their occasional but very rare occurrence in open water of Lake Michigan was corroborated by Cook Power Plant collections (unpublished data, Great Lakes Research Division).

Green Sunfish

Green sunfish occurred in impingement samples taken at the J. H. Campbell Plant in 1978. This species has, however, never been collected in Pigeon Lake (Jude et al. 1981a). One YOY green sunfish (39 mm) was trawled at 9 m in Lake Michigan during 1979. No adult or larval green sunfish have been collected in Lake Michigan during the 4-yr study. These data suggest that this species rarely enters the Lake Michigan habitat near the Campbell Plant.

Pumpkinseed

Pumpkinseed is a common species in Pigeon Lake. During the 4-yr study no adult pumpkinseeds were observed in Lake Michigan samples. One YOY pumpkinseed (40 mm) was seined at north transect beach station R during October 1977 in a water temperature of 10 C and one YOY pumpkinseed was caught in a larval sled tow at 1.5 m, north transect during September 1977 in a water temperature of 17.5 C. These pumpkinseeds probably came from Pigeon Lake or the discharge canal. Unidentified Lepomis spp. larvae collected in Lake Michigan during 1977, 1979 and 1980 (see RESULTS AND DISCUSSION, Bluegill) were probably pumpkinseed or bluegill larvae. These larvae were probably transported by currents from the discharge canal to Lake Michigan.

Logperch

Logperch was scarce in the study area. A few logperch were collected in Pigeon Lake during 1979. A larval logperch was collected in Lake Michigan at the 12-m contour on the south transect during 1978. No juvenile or adult logperch were caught during the 4-yr study. SCUBA divers, however, observed logperch near the riprap of the jetties at the mouth of Pigeon Lake during 1978 and 1979 and near the riprap of the Unit 3 intake during 1981.

Smallmouth Bass

Over the 4 yr, only two smallmouth bass were collected in Lake Michigan near the Campbell Plant; both were collected in late summer 1978 at stations 1-1.5 m in depth. Additional sporadic sightings of this species near the rock base of the Pigeon Lake - Lake Michigan jetties occurred in 1978-1980. As was observed at the D. C. Cook Power Plant (Jude et al. 1980), occasional transient smallmouth bass will probably be attracted to the rocky substrate near the intake and discharge area; however, no adverse plant impact on this species was observed or is expected.

Bluntnose Minnow

The bluntnose minnow occurs in lakes, ponds, rivers and creeks (Scott and Crossman 1973). Although it is common inland (Becker 1976), it was not frequently collected in Lake Michigan during our study. Bluntnose minnows are common in Pigeon Lake (Jude et al. 1981a), but only 19 have been taken in Lake Michigan: 15 in 1978 and 4 in 1979.

Of the 19 bluntnose minnows captured, 12 (25-44 mm) seined in September 1978 at beach stations R (north discharge) and P (south reference) and three fish 37-42 mm seined at station P (south reference) in October 1979 were probably YOY (Westman 1938). The remaining four fish, 45-74 mm, were yearlings or adults; three were seined from the three beach stations and one was trawled at station D (9 m, south). All bluntnose minnows were collected from August to November; most during the night. Water temperatures at which fish were collected ranged from 12.8 to 26 C; the largest single catch of bluntnose minnows was in September 1978 at station R at 19 C (12 fish). All bluntnose minnows collected were immature or sex could not be determined. No bluntnose minnow larvae were collected in Lake Michigan during our study.

Goldfish

The goldfish is an east Asian species which has been introduced in North America. It has become abundant in shallow, vegetated, warm-water areas of the Great Lakes region such as Lake St. Clair and Lake Erie (Scott and Crossman 1973). Only one goldfish was collected in Lake Michigan during our study. In July 1978 a 73-mm immature goldfish was seined at beach station Q (south discharge) at a water temperature of 19.0 C. A few goldfish have been collected from Pigeon Lake, but they are not common there (Jude et al. 1981a).

Fathead Minnow

The fathead minnow occurs in a variety of habitats, including lakes, ponds and small streams (Scott and Crossman 1973). However, they were rare in our collections in Lake Michigan as only two were captured there, one each during August 1978 and April 1979 (the latter one a fry taken during larval fish sampling). Their occurrence in the area appears to be incidental.

Damaged Larvae

Introduction--

In the course of sample collection there are a number of factors which may result in damage to larval fish specimens. The primary cause of larvae damage is abrasion, which occurs when sand and other debris grind against specimens during net tows and the subsequent sample processing. With few notable exceptions, highest densities of damaged larvae occurred at the beach and 1.5-m sampling stations. These areas have the greatest turbulence which cause suspended sand and debris to be in highest occurrence in the samples where they exhibit maximum abrasive effect. Another component of the damaged larvae classification may be those larvae which died prior to our sampling and

were subsequently collected during sampling. These dead larvae probably exhibit varying degrees of decomposition, often making them impossible to distinguish from larvae which were subjected to abrasion.

When damage does occur to a larva, all practical methods were employed to identify the larva to species. In some instances, however, elimination of body parts or obscuring of pigmentation patterns precluded larva identification. Hereafter, use of the term "damaged larvae" will refer to those larvae which were unidentified due to excessive damage.

When larvae are damaged beyond recognition, we can speculate as to their identity based on the identity of larvae caught coincidentally in the same or adjacent samples. A summary of those larvae caught coincidentally with damaged larvae is presented in Table 54. Adjustment calculations to known species caught coincidentally with damaged larvae can be made assuming that all species were equally susceptible to damage. Thus each species would be represented among the damaged larvae in approximately the same proportion that they existed in the identified component. The other assumption is that damaged larvae belong to a species which was represented in the sample. It was not possible to test the strength of each of these assumptions, however, there was a clear indication that, based on length-frequency data, in some instances, these assumptions were violated.

The following is a year-by-year summary of the occurrences of damaged larvae in our samples. Although there are instances when considerable adjustments of known larvae densities would result if damaged larvae were assigned to species based on their proportional occurrence in the samples, each case was carefully reviewed and it was determined that over the 4 yr these adjustments, if made, would not have affected our results or conclusions about any known species of larval fish in the area.

1977--

During 1977, 18 samples contained damaged larvae. In eight of these samples, the only identifiable larvae present were alewives, thus making it highly probable that damaged larvae were also alewives. Despite projected adjustments of up to 100% on the reported densities of larval alewives (Table 54), we feel that these adjustments would not have significantly altered reported larval alewife distributional trends. The highest percent adjustments for larval alewives would have been made on the lowest larval alewife densities. Eight samples collected in 1977 contained more than one identifiable species of larvae coincident with damaged larvae. In six of these cases the resultant adjustments to all species present would have been less than 10%, while the remaining two cases would require adjustments of 31.2 and 76.8%, involving both alewives and spottail shiner larvae. There were only two samples collected in 1977 which contained only damaged larvae. In each of these cases, assignment to alewife, spottail shiner or yellow perch was feasible; however, the low densities reported would not have altered observed trends for these species.

Table 54. Densities of all species of larvae in samples containing damaged larvae taken at the J. H. Campbell Plant, eastern Lake Michigan 1977-1980. Species of co-occurring larvae are given in parentheses. See Table 9 for species codes. * denotes sled tow samples.

Transect	Date	Station	Depth Strata (m)	Density of damaged larvae (no/1000 m³)	Density of co-occurring larvae (no/1000 m³)
			1977		
North	6-03	L	6.0	79	None
	7-07	R	0	138	10021(AL),7562(SP)
	7-07	R	0	296	7671(AL),10490(XM),591(CP)
	7-13	I	0	39	4396(AL),39(YP),231(SP)
	7-13	J	0	56	2193(AL)
	7-13	N	8.0	22	311(AL)
	7-13	O	6.0	25	2511(AL)
	7-25	Q	0	2286	6090(AL),6464(XM),12954(SP)
	7-26	R	0	146	292(AL)
	8-15	I	0	27	27(AL)
South	6-17	D	6.0	22	None
	7-07	A	0	79	2786(AL),3525(XM)
	7-07	B	0	185	180(AL),40(XM),21(SP)
	7-09	E	6.0	181	554(AL),25(XM)
	7-09	G	0	184	854(AL)
	7-10	H	15.0	27	56(AL)
	*7-20	D	9.0	35	385(AL)
	*7-21	B	3.0	552	715(AL),10566(XM),6791(SP)
			1978		
North	6-06	I	0	38	190(AL),38(SP)
	6-07	Q	0	1626	1626(SP),813(YP)

Table 54 (continued).

Transect	Date	Station	Depth Strata (m)	Density of damaged larvae (no/1000 m³)	Density of co-occurring larvae (no/1000 m³)
	6-07	L	4.0	31	1545(AL),79(YP)
	6-07	L	2.0	39	39(AL)
	6-07	N	8.0	14	175(AL),14(YP)
	*6-07	Q	1.0	90	1400(AL),180(SP)
	*6-19	J	3.0	80	None
	6-23	L	0	21	21(SM)
	7-01	O	3.0	21	1003(AL),21(SM)
	7-01	O	11.0	13	134(AL),26(YP)
	7-01	W	0	19	589(AL),38(YP)
	7-01	W	4.0	36	1009(AL),36(YP)
	7-02	R	0	70	70(AL),354(SP)
	7-02	J	0	32	525(AL)
	7-02	J	2.0	79	2840(AL),118(SP)
	7-02	L	0	19	1588(AL)
	7-02	N	4.0	35	248(AL)
	7-02	N	6.0	108	440(AL)
	7-02	N	2.0	1046	5028(AL),95(SM)
	*7-02	I	1.5	36	254(AL),108(SP),110(SM)
	*7-19	I	1.5	50	150(AL),50(SP)
	7-19	O	0.5	17	436(AL)
	7-21	L	6.0	16	68(AL)
	7-21	N	2.0	31	373(AL)
	7-21	N	4.0	16	102(AL)
	7-21	O	9.0	17	54(AL)
	8-01	L	4.0	16	211(AL)
	8-01	O	0.5	33	938(AL)
	8-01	W	4.0	35	260(AL)
	8-01	W	12.0	26	27(AL)
	*8-01	I	1.5	29	4140(AL),59(SP),89(SM)
	*8-01	J	3.0	49	343(AL)

Table 54 (continued).

Transect	Date	Station	Depth Strata (m)	Density of damaged larvae (no/1000 m³)	Density of co-occurring larvae (no/1000 m³)
	8-02	L	4.0	40	700(AL),40(SP)
	8-02	N	8.0	181	None
	8-17	L	4.0	75	534(AL)
	8-17	L	2.0	683	1441(AL)
	8-17	N	2.0	51	633(AL)
			1978		
South	5-15	P	0	97	488(YP)
	5-17	D	0	17	17(YP)
	5-18	A	1.5	53	185(YP),53(BR)
	6-05	B	2.0	51	775(AL)
	6-06	C	0	17	499(AL)
	6-06	D	2.0	19	114(AL)
	6-19	F	14.0	15	None
	6-22	D	2.0	29	29(YP)
	6-22	E	11.0	33	33(YP),33(SM)
	7-01	C	0	546	5621(AL),40(SM)
	7-01	C	6.0	52	1108(AL)
	7-01	C	0	39	2211(AL),19(YP)
	7-01	D	2.0	371	1645(AL),43(YP)
	7-01	D	6.0	23	618(AL),23(YP)
	7-01	D	4.0	44	627(AL),44(YP)
	7-01	E	0	405	1824(AL)
	7-01	E	3.0	334	2043(AL),20(YP)
	7-01	E	6.0	20	506(AL),20(YP)
	7-01	E	9.0	47	318(AL)
	7-01	E	6.0	23	600(AL),23(YP),23(CP)
	7-01	F	8.0	42	258(AL),21(SM)

Table 54 (continued).

Transect	Date	Station	Depth Strata (m)	Density of damaged larvae (no/1000 m³)	Density of co-occurring larvae (no/1000 m³)
	7-01	F	8.0	23	170(AL),23(SM)
	*7-03	C	6.0	78	3796(AL),313(SP)
	*7-03	D	9.0	26	419(AL)
	7-19	D	4.0	17	278(AL)
	7-19	D	8.0	18	520(AL)
	7-19	E	3.0	15	160(AL),15(XX)
	7-19	E	6.0	17	138(AL)
	7-19	E	9.0	100	340(AL)
	7-19	F	4.0	18	72(AL),18(YP)
	8-01	C	2.0	18	3315(AL)
	8-01	C	4.0	36	1020(AL)
	8-01	D	4.0	86	121(AL)
	*8-02	F	15.0	25	None
	*8-02	D	9.0	128	801(AL)
	*8-02	C	6.0	111	1633(AL)
	*8-02	B	3.0	166	41(AL),123(SP)
	*8-03	B	3.0	98	852(AL)
	*8-04	A	1.5	35	568(AL),891(SP)
	*8-04	P	1.0	246	328(AL),82(SP)
	*8-04	P	1.0	541	2052(AL),1621(SP)
	*8-04	C	6.0	36	656(AL)
			1979		
North	*6-04	J	3.0	55	None
	6-19	N	6.5	14	14(SM)
	7-03	J	2.5	74	76(AL)
	*7-03	J	3.0	103	None
	7-03	L	4.0	31	96(AL),31(SM),31(YP)

Table 54 (continued).

Transect	Date	Station	Depth Strata (m)	Density of damaged larvae (no/1000 m^3)	Density of co-occurring larvae (no/1000 m^3)
	7-03	N	0.5	16	96(AL),65(YP)
	7-03	N	0	16	80(AL),16(SM),64(YP)
	7-03	W	4.5	14	14(AL)
	7-03	W	0	16	81(AL),66(YP)
	7-17	Q	0.5	215	5392(AL),431(SP)
	*7-17	Q	1.0	448	149(AL),3588(SP)
	*7-17	Q	1.0	85	255(SP)
	*7-18	R	1.0	191	382(SP)
	7-19	L	0.5	14	43(AL)
	*8-01	Q	1.0	777	3885(AL),22801(SP)
	*8-01	Q	1.0	262	261(AL),7354(SP),87(YP),87(ES)
	8-01	R	0.5	305	15592(AL),610(SP)
	8-01	R	0.5	193	5602(AL)
	8-01	R	0.5	215	4515(AL),7740(SP)
	*8-01	I	1.5	1780	1184(AL),32048(SP),296(CP)
	8-02	L	0.5	17	262(AL)
	8-21	N	2.5	13	707(AL)
	8-21	N	3.0	26	585(AL)
	8-21	N	6.0	33	721(AL)
	9-19	O	9.0	11	22(AL)
South	5-14	P	0.5	318	637(YP)
	*5-15	B	3.0	63	63(YP),63(CP)
	5-15	C	2.0	21	21(YP),129(GS)
	5-15	D	6.0	57	28(SM),28(GS)
	5-15	D	0.5	19	135(GS)
	5-15	D	2.5	16	16(BR)
	*5-16	A	1.5	39	118(YP)
	6-05	B	2.5	77	None
	*6-19	A	1.5	4600	4600(SP)

Table 54 (continued).

Transect	Date	Station	Depth Strata (m)	Density of damaged larvae (no/1000 m^3)	Density of co-occurring larvae (no/1000 m^3)
	7-02	B	0.5	31	125(AL)
	*7-02	C	6.0	34	897(AL),34(YP)
	7-02	D	8.5	15	None
	*7-17	A	1.5	71	427(AL),142(SP)
	*8-01	P	1.0	368	4416(AL),15456(SP)
	8-20	C	0.5	14	254(AL)
	8-20	F	4.5	18	440(AL)
	9-17	C	0.5	15	396(AL)
			1980		
North	*6-16	R	1.0	242	242(AL),242(YP)
	*7-01	O	12.0	36	1757(AL),36(TP) 146(SS),36(NS)
	7-02	O	11.0	26	5312(AL),934(SP) 52(YP)
	7-14	N	4.5	16	1925(AL),16(YP)
	7-14	W	0.5	16	1609(AL),178(SP)
	*7-16	N	9.0	43	1020(AL),63(SP) 87(JD),109(TP)
	*8-04	Q	1.0	310	5584(AL),24815(SP)
	*8-05	Q	1.0	33	198(AL),3762(SP)
	8-18	O	3.0	9	63(AL)
South	7-01	P	0.5	404	404(AL)
	*7-01	C	5.5	70	3990(AL),35(SP)
	7-01	D	2.5	20	11749(AL),165(SP)
	7-01	E	6 0	22	2300(AL),46(SP),22(YP) 22(NS)

Table 54 (continued).

Transect	Date	Station	Depth Strata (m)	Density of damaged larvae (no/1000 m³)	Density of co-occurring larvae (no/1000 m³)
	7-01	E	9.0	21	1154(AL),44(SP)
	7-14	P	0.5	238	7868(AL),25318(SP)
	7-14	C	5.5	11	1210(AL),22(SP),34(YP)
	7-14	E	0.5	42	6828(AL),21(SP)
	7-14	F	0.5	16	1696(AL),80(SP),16(YP)
	*7-15	B	3.0	29	116(AL),731(SP)
	8-04	P	0.5	224	2016(AL),1344(SP)
	8-05	C	0.5	12	289(AL)
	8-05	D	0.5	12	74(AL),12(JD)
	8-05	E	11.0	15	64(AL)
	*8-06	P	1.0	2300	16100(AL),50600(SP)

1978--

Of the 81 samples collected in 1978 containing damaged larvae, adjustments to known categories in the samples would have resulted in less than 10% increases in 39 cases. In 19 of the remaining samples, alewife was the only concurrently captured, known species, thus it is highly probable that damaged larvae in these samples were alewives. Yellow perch was the only concurrently caught species in three of the samples, while smelt was the only concurrently captured species in one sample. It seemed warranted, based on time of occurrence and concurrently caught larvae, to designate the damaged larvae in the former sample as yellow perch. The identity of the larva in the latter sample, which concurrently contained only smelt larvae, was probably an alewife. This larva was 4.0 mm in late June, which was considered too small for a smelt hatched during spring 1978.

Of the 19 remaining 1978 samples containing damaged larvae, 15 samples contained a mixture of known species, making determination of the identity of these damaged larvae difficult. Proportionally assigning damaged larvae to species, based on the proportion each of the known species made up of the sample would not result in any significant alteration of the results for these species with two notable exceptions. The sample taken at beach station Q (south discharge) on 7 June would have contained an inordinate density of yellow perch if 66.7% of the damaged larvae were speculated to be yellow perch. Length-frequency data show that larvae causing the high density of damaged larvae were 5.0 mm and were more likely unknown minnow or spottail shiner larvae. Additionally, the size range of 3.0-5.0 mm of damaged larvae caught at station N (9 m, north) at the 2-m depth stratum in early July 1978 makes it more probable that they were alewives and precludes their classification as smelt.

Four samples collected in 1978 contained only damaged larvae. With the exception of the larva caught in late June at station F (15 m south), which we believe was a smelt based on its total length of 19 mm, all remaining damaged larvae in these samples were probably alewives.

1979--

Of the 42 samples collected in 1979 which contained damaged larvae, 18 samples would require adjustments of less than 10% if damaged larvae were proportionally assigned to concurrently captured species. Thirteen of the samples contained a single concurrently caught, known species, and assignment to that respective species would not have altered our conclusions about these species. Similarly, proportional assignment of damaged larvae in samples which concurrently contained a mixture of known species would not have significantly affected our conclusions about the distributional and abundance trends of these species.

There were only four samples collected in 1979 in which only damaged larvae were found. It is probable that those damaged larvae observed in early June 1979 were smelt; whereas, those observed in early July were alewives.

1980--

Of the 24 samples containing damaged larvae in 1980, only 5 would require adjustments of more than 10% if damaged larvae were proportionally assigned to species. In four of these cases, alewives were the lone or predominant species, and it is probable that damaged larvae in these samples were mostly alewives. In the single case of the sled tow at beach station R (north discharge) on 16 June 1980, there appeared to be equal probability that the damaged larvae were yellow perch or alewives. In all cases where damaged larvae alone were caught in the sample, the resultant densities were too low to cause a significant change in our results.

FISH EGGS

Introduction

Occurrence of fish eggs in the study area gives added support to the contention that the inshore zone near the Campbell Plant is used as a spawning site for a number of Lake Michigan species. While the nondescript appearance of many fish eggs precludes their identification, we can, based on our knowledge of the biology of indigenous species, make some speculation on the identity of eggs collected.

We feel that the majority of fish eggs in our samples were those of spottail shiners and alewives. Additional species which are thought to spawn in the study area are yellow perch, trout-perch, smelt, emerald shiner, burbot, slimy sculpin, ninespine stickleback, johnny darter, white sucker, longnose sucker, gizzard shad, lake trout and coregonids. Due to the fact that slimy sculpins and ninespine sticklebacks lay their adhesive eggs within nests and johnny darters lay their adhesive eggs on the bottom of submerged objects, it was unlikely that we sampled the eggs of these species. White suckers and longnose suckers were more apt to spawn in streams, and also have comparatively larger eggs which would facilitate identification. Trout-perch eggs contain an oil globule which would aid in distinguishing it from alewife or spottail shiner eggs. Burbot eggs were eliminated from consideration due to their occurrence in late winter. No field sampling was conducted in January-March when the eggs of this species might be expected. Burbot eggs were collected during December at the D. C. Cook Plant (Jude et al. 1979b). Eggs of emerald shiners have a large perivitelline space which would facilitate separation from all other eggs. Eggs of yellow perch and smelt are highly characteristic and could easily be identified. Gizzard shad eggs could possibly be in our samples; however, absence of spawning adults in the area diminishes the possibility, with the exception of those eggs originating in the discharge canal. Lake trout eggs were observed in the stomachs of round whitefish collected in gill nets in November 1980, and SCUBA divers in a non-project dive found lake trout eggs within the newly laid riprap.

Undoubtedly the most effective gear for sampling fish eggs was the benthic sled. This gear was only consistently used during 1978-1980. The less consistent use of the benthic sled in 1977 is a reason for the lower mean fish egg densities reported and precludes inclusion of 1977 data in meaningful year to year comparisons.

Seasonal Distribution

April--

Fish eggs first occurred in April of only one of the 4 yr sampled (1978) (Figs. 91-100). Since these eggs were found only at the north transect during April 1978, we suspect the origin of the fish eggs was the discharge canal. Warmer water temperatures there undoubtedly facilitated early spawning of resident species. It is possible that these eggs were those of gizzard shad which are known to spawn in the discharge canal. Mean densities of eggs present (less than 2 eggs/1000 m^3) suggested either very limited spawning, or an extremely high dilution of the discharge water with Lake Michigan water in the sampling area.

May--

During all years when sampling was conducted in May, fish eggs were only collected at the north transect; densities were less than 50/1000 m^3. Again this may suggest a contribution of eggs from the discharge canal or it may reflect some limited initial spawning in Lake Michigan near the discharge. If eggs we collected were the result of spawning occurring in Lake Michigan during May of these years, it was likely that alewife or spottail shiner were the species involved.

Early June--

The first occurrence of fish eggs at both transects occurred in early June of all years sampled. In all years at all depth groups, except 12-15 m during 1978, north transect fish egg densities exceeded those of the south transect, which further suggests either a contribution of fish eggs from the discharge canal or a higher level of spawning activity in the area of the discharge canal compared with the reference transect. With few exceptions, the difference in mean water temperature between transects was generally less than 1.5 C. A comparison of mean egg densities among years indicates there was more intense spawning activity in early June 1978 and 1980 compared with 1979, which appeared to be related to water temperature. The highest inshore water temperatures were present in 1978 coincident with highest early June fish egg production, while lowest early June fish egg production in 1979 corresponded to generally lower water temperatures. With the exception of the high mean density of fish eggs at the 12- and 15-m south transect stations in early June 1978, there was a distinct trend toward decreased mean egg densities with increased water depth (Figs. 91-100).

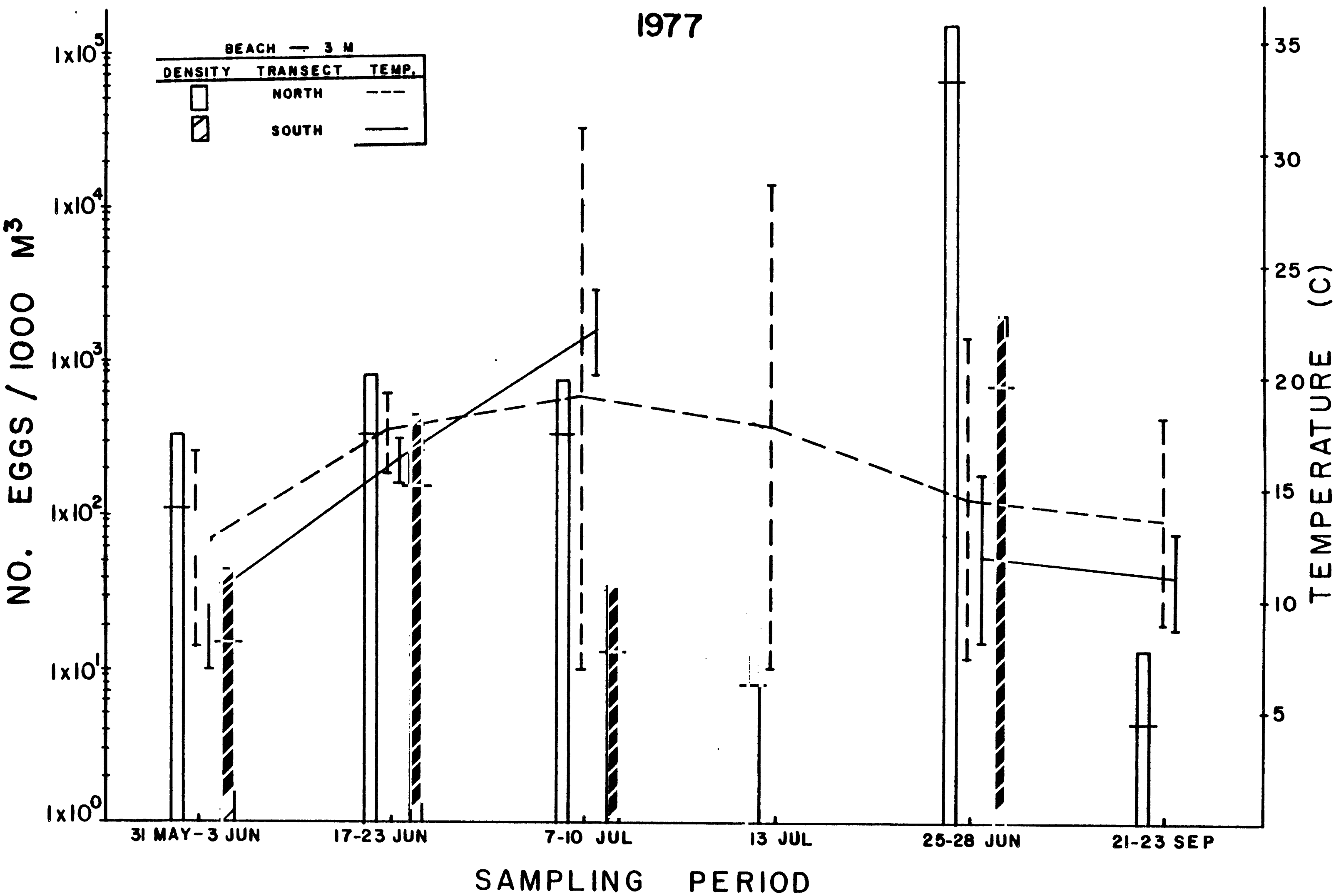


Fig. 91. Density (no./1000 m^3 plotted on log scale) of fish eggs collected during June to September 1977 at beach - 3 m (all contours, depth strata and diel periods pooled) near the J. H. Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S. E. Midpoint of water temperature range (vertical line) at time of collection is shown.

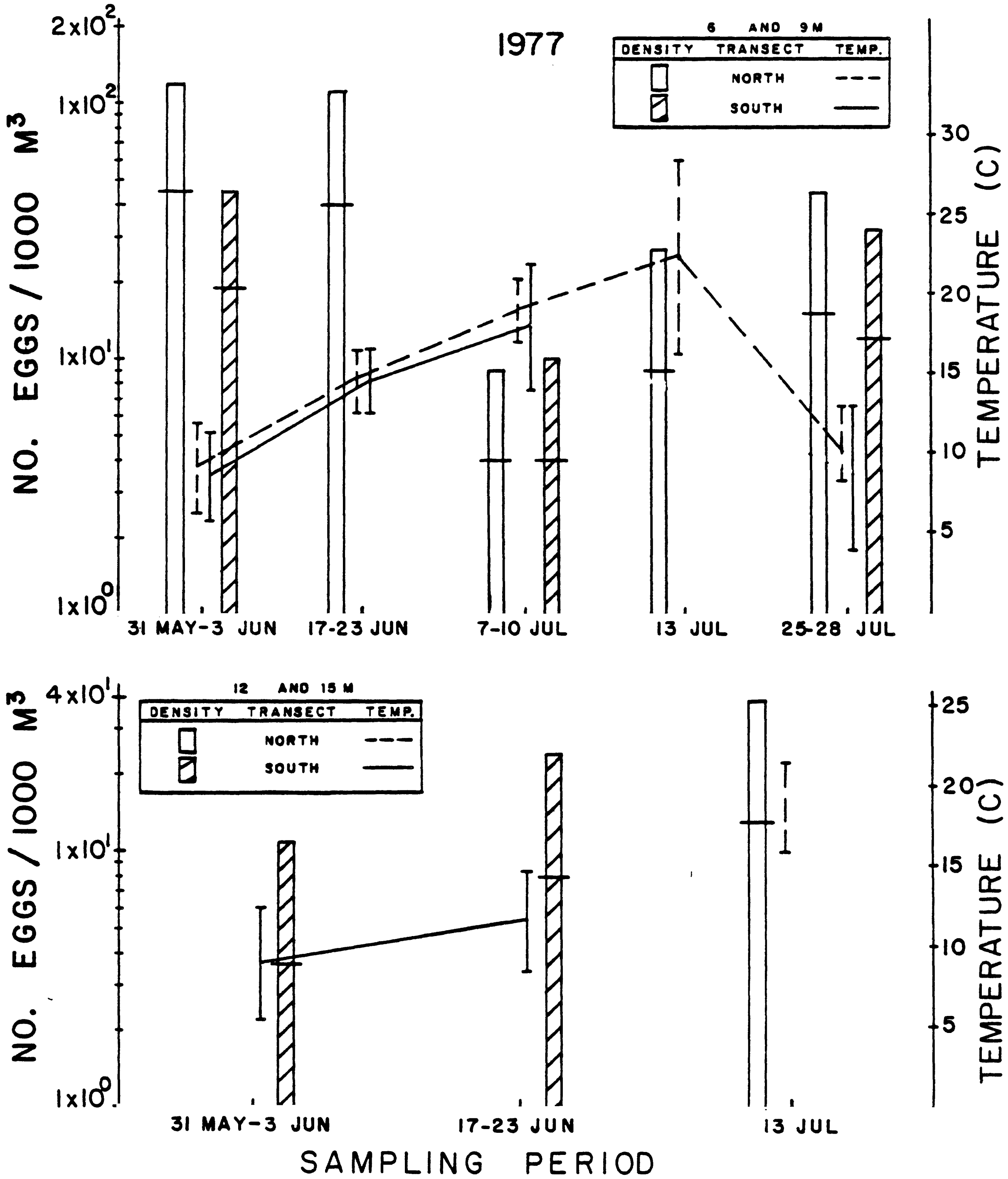


Fig. 92. Density (no./1000 m^3 plotted on log scale) of fish eggs collected during June to September 1977 at 6 and 9 m, 12 and 15 m (all contours, depth strata and diel periods pooled) near the J. H. Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S. E. Midpoint of water temperature range (vertical line) at time of collection is shown.

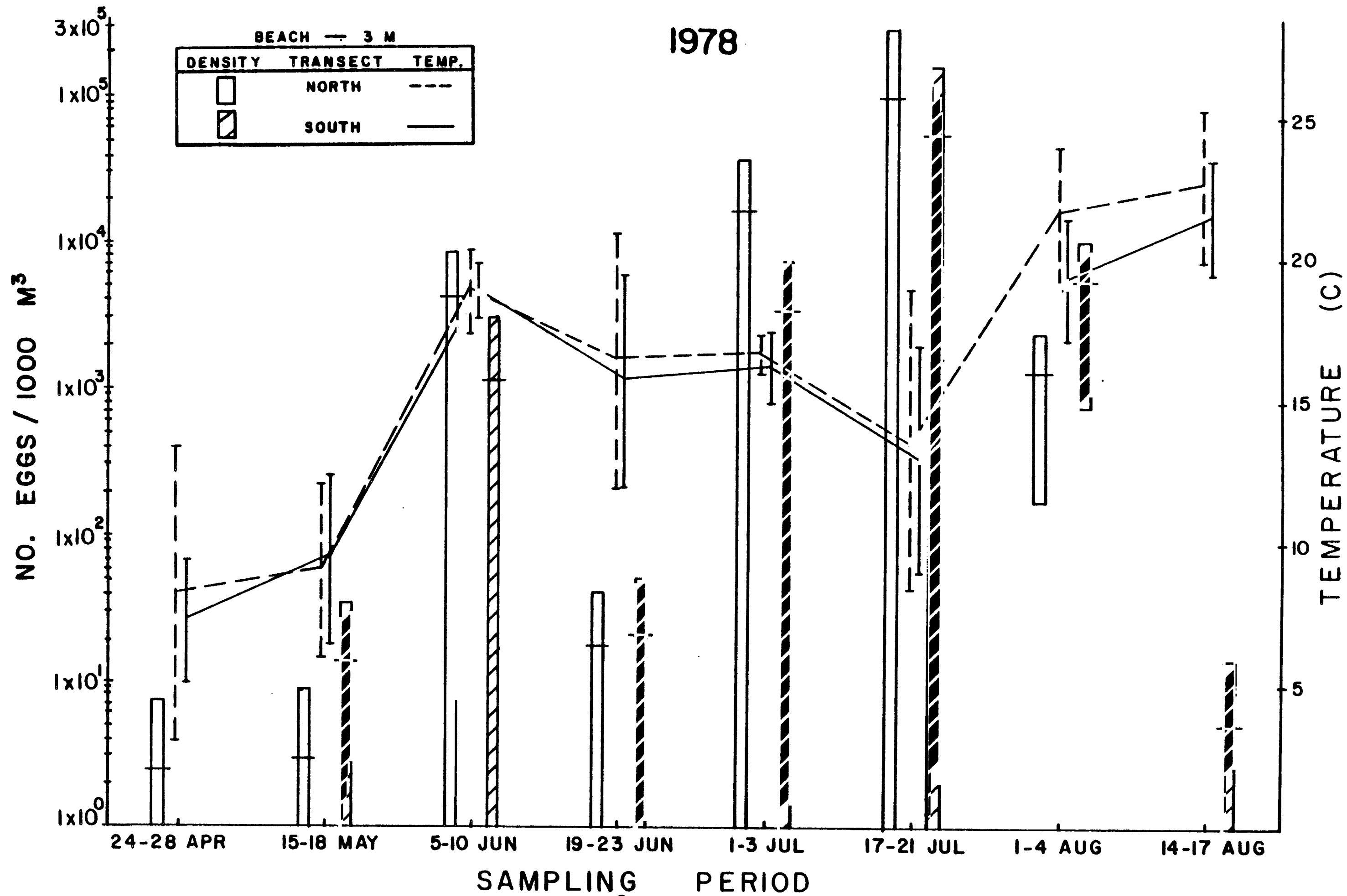


Fig. 93. Density (no./1000 m^3 plotted on log scale) of fish eggs collected during April to September 1978 at beach - 3 m (all contours, depth strata and diel periods pooled) near the J. H. Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S. E. Midpoint of water temperature range (vertical line) at time of collection is shown.

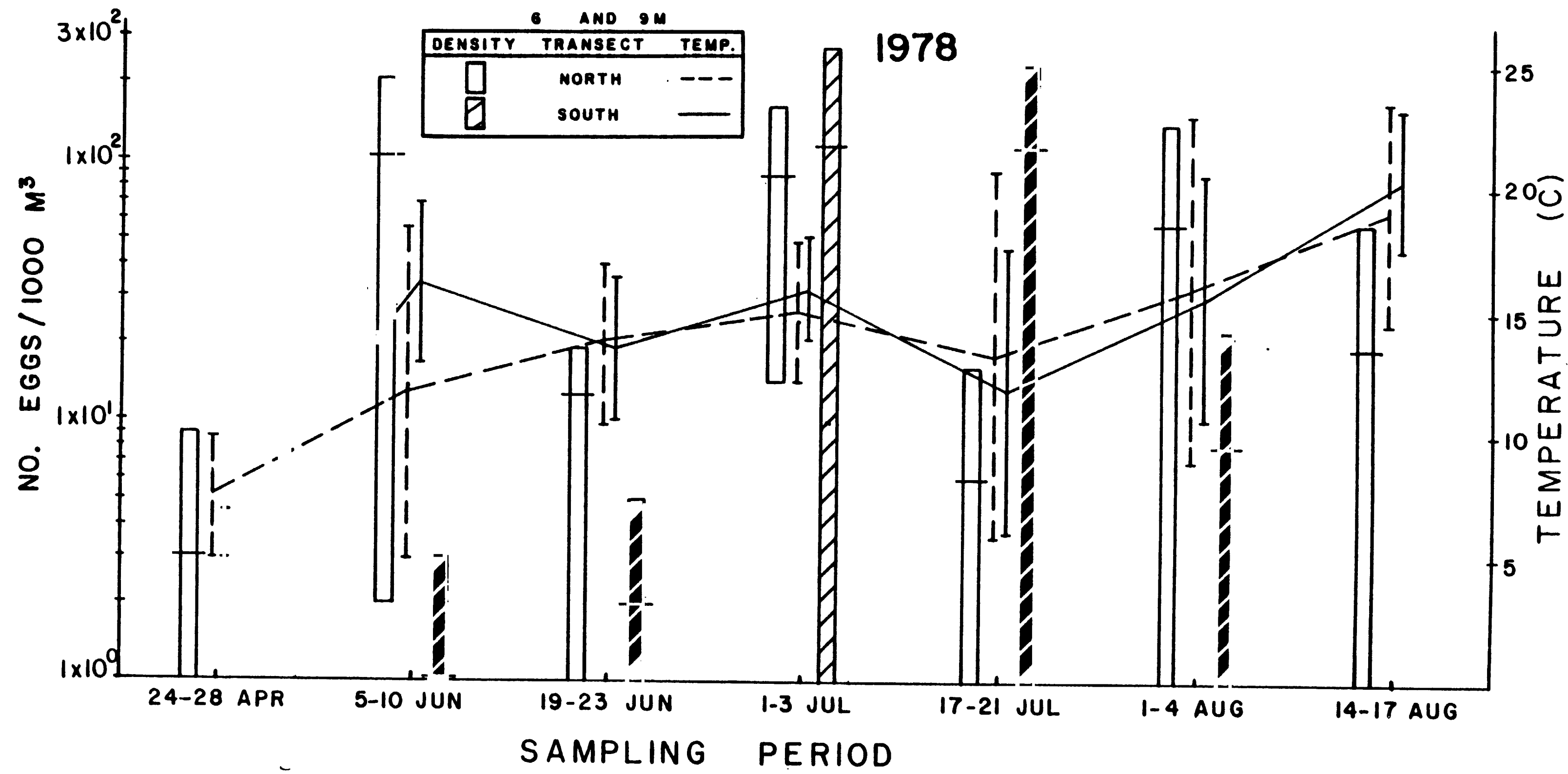


Fig. 94. Density (no./1000 m^3 plotted on log scale) of fish eggs collected during April to September 1978 at 6 and 9 m (all contours, depth strata and diel periods pooled) near the J. H. Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S. E. Midpoint of water temperature range (vertical line) at time of collection is shown.

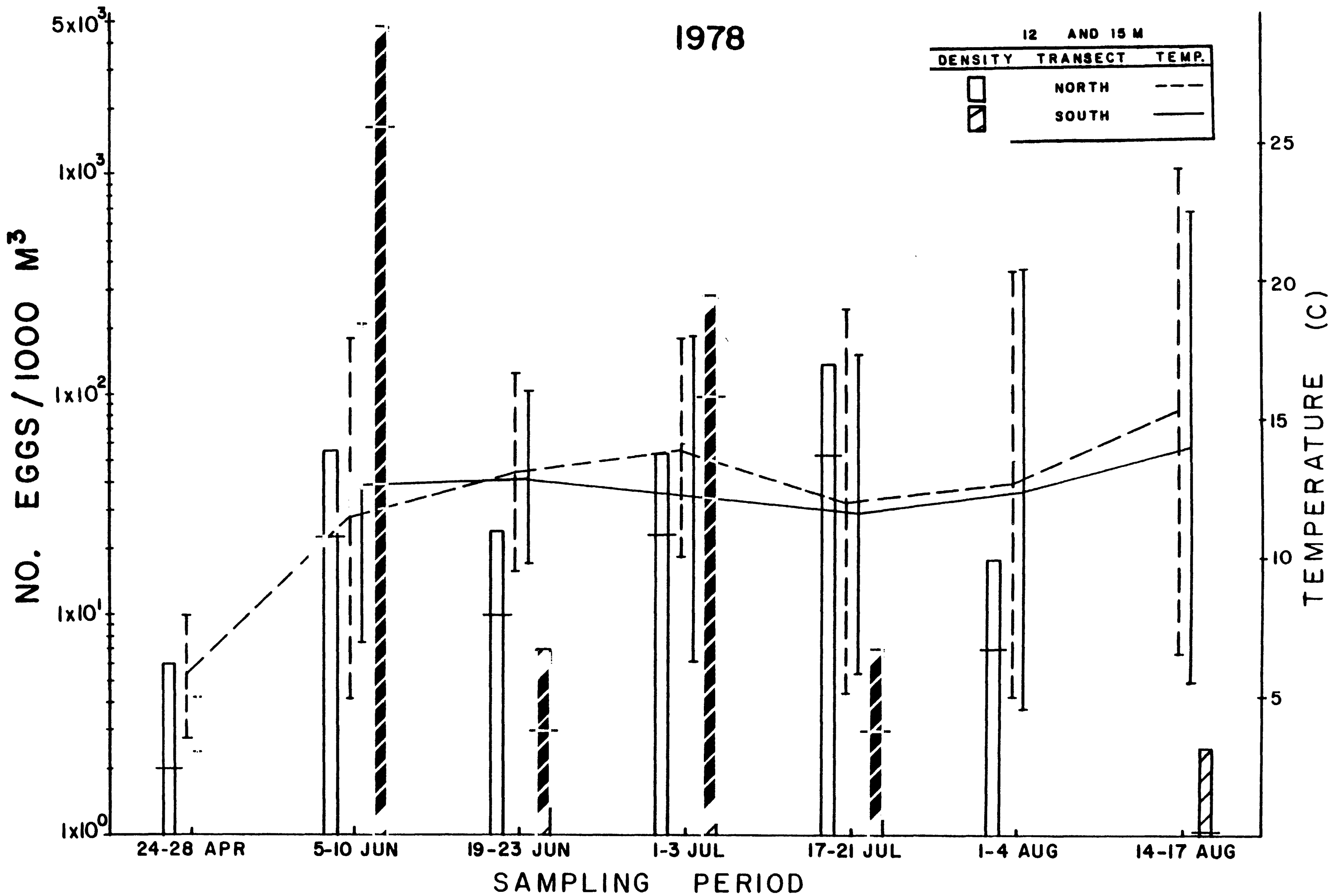


Fig. 95. Density (no./1000 m^3 plotted on log scale) of fish eggs collected during April to September 1978 at 12 and 15 m (all contours, depth strata and diel periods pooled) near the J. H. Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S. E. Midpoint of water temperature range (vertical line) at time of collection is shown.

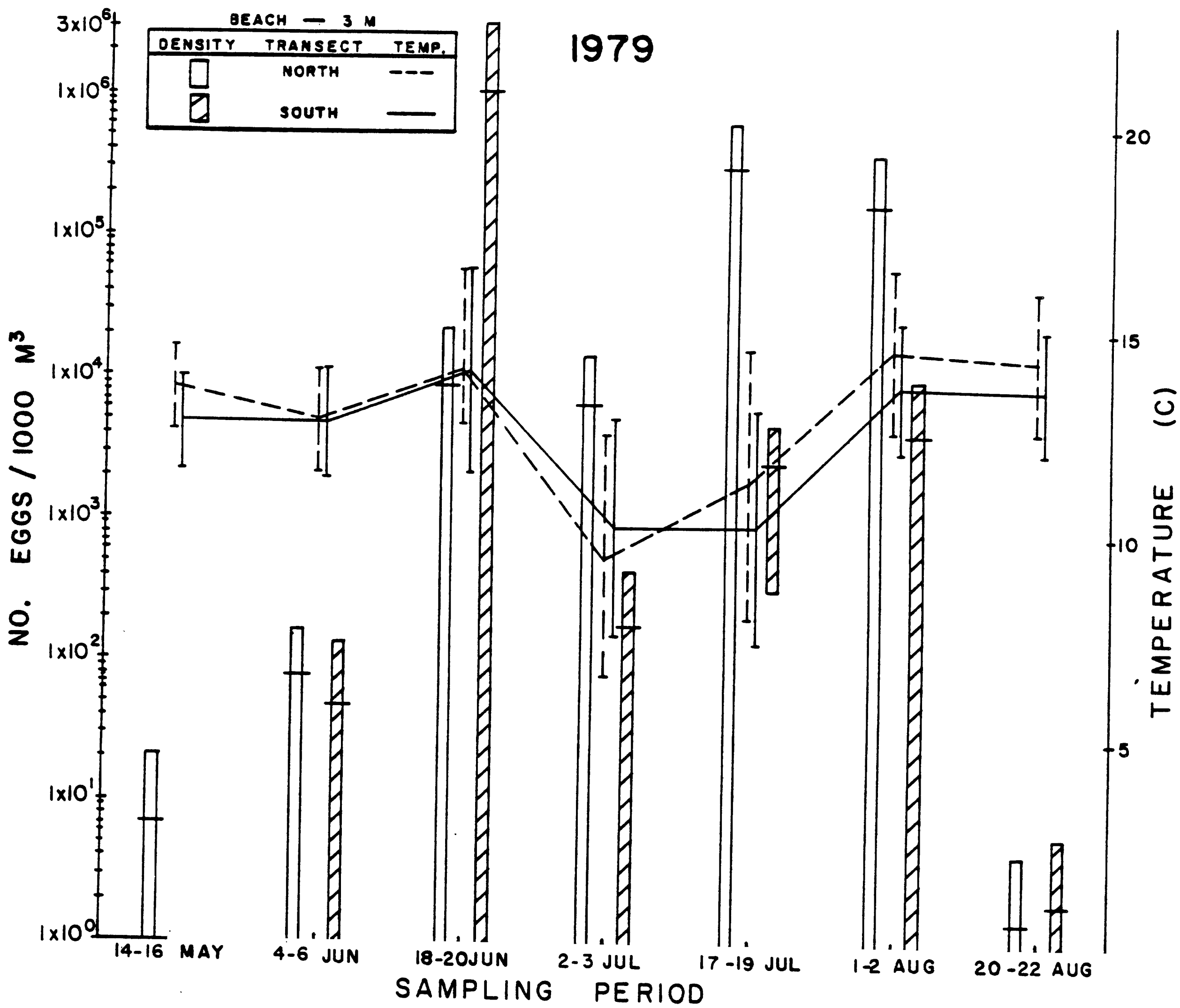
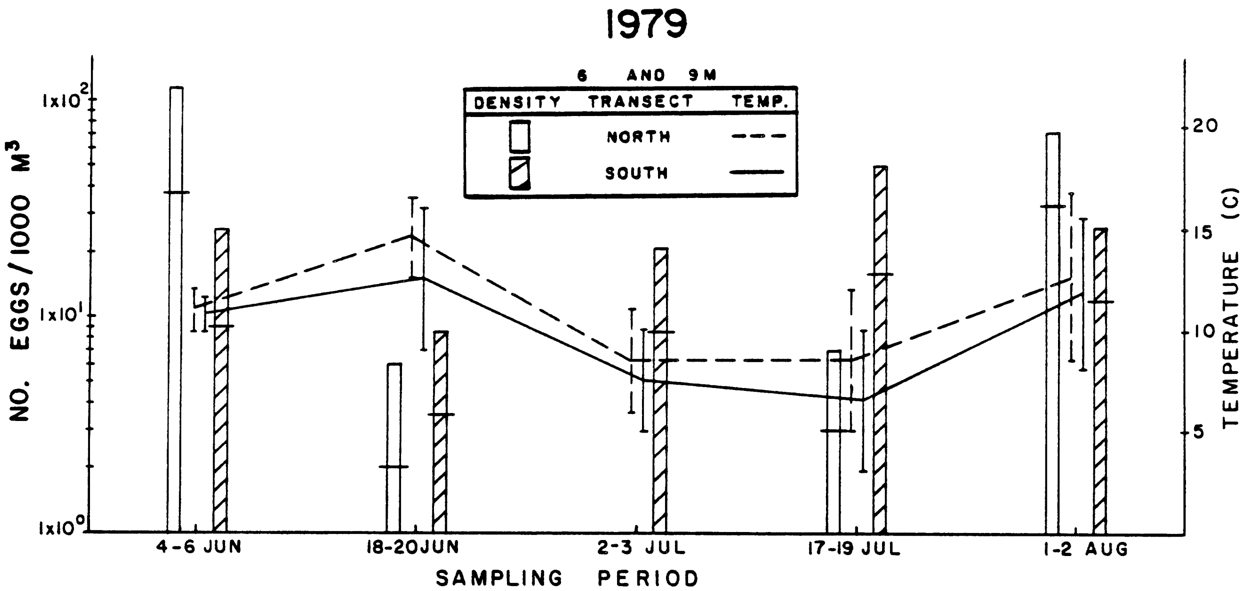


Fig. 96. Density (no./1000 m^3 plotted on log scale) of fish eggs collected during April to September 1979 at beach - 3 m (all contours, depth strata and diel periods pooled) near the J. H. Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S. E. Midpoint of water temperature range (vertical line) at time of collection is shown.



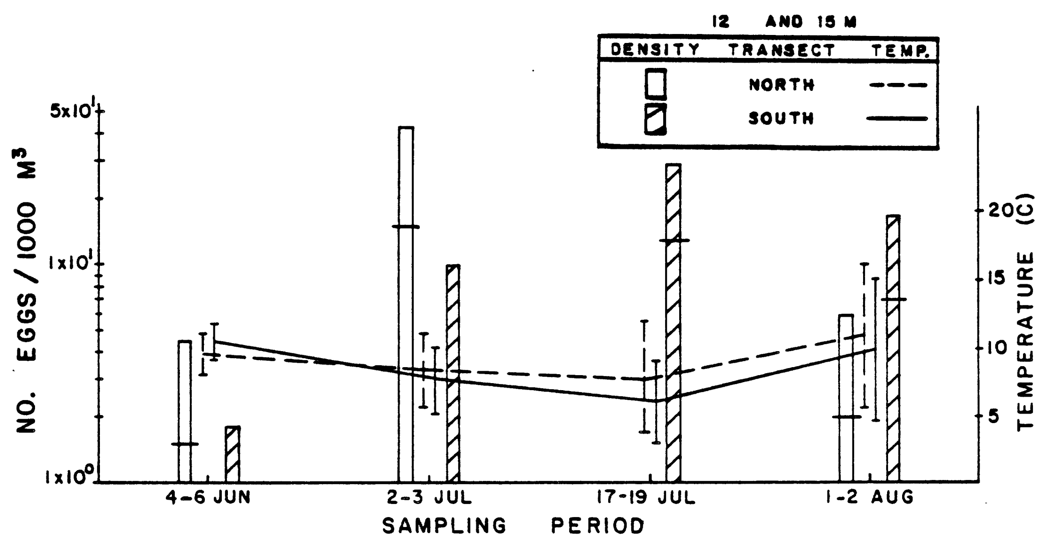


Fig. 97. Density (no./1000 m^3 plotted on log scale) of fish eggs collected during June to September 1979 at 6 and 9 m, 12 and 15 m (all contours, depth strata and diel periods pooled) near the J. H. Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S. E. Midpoint of water temperature range (vertical line) at time of collection is shown.

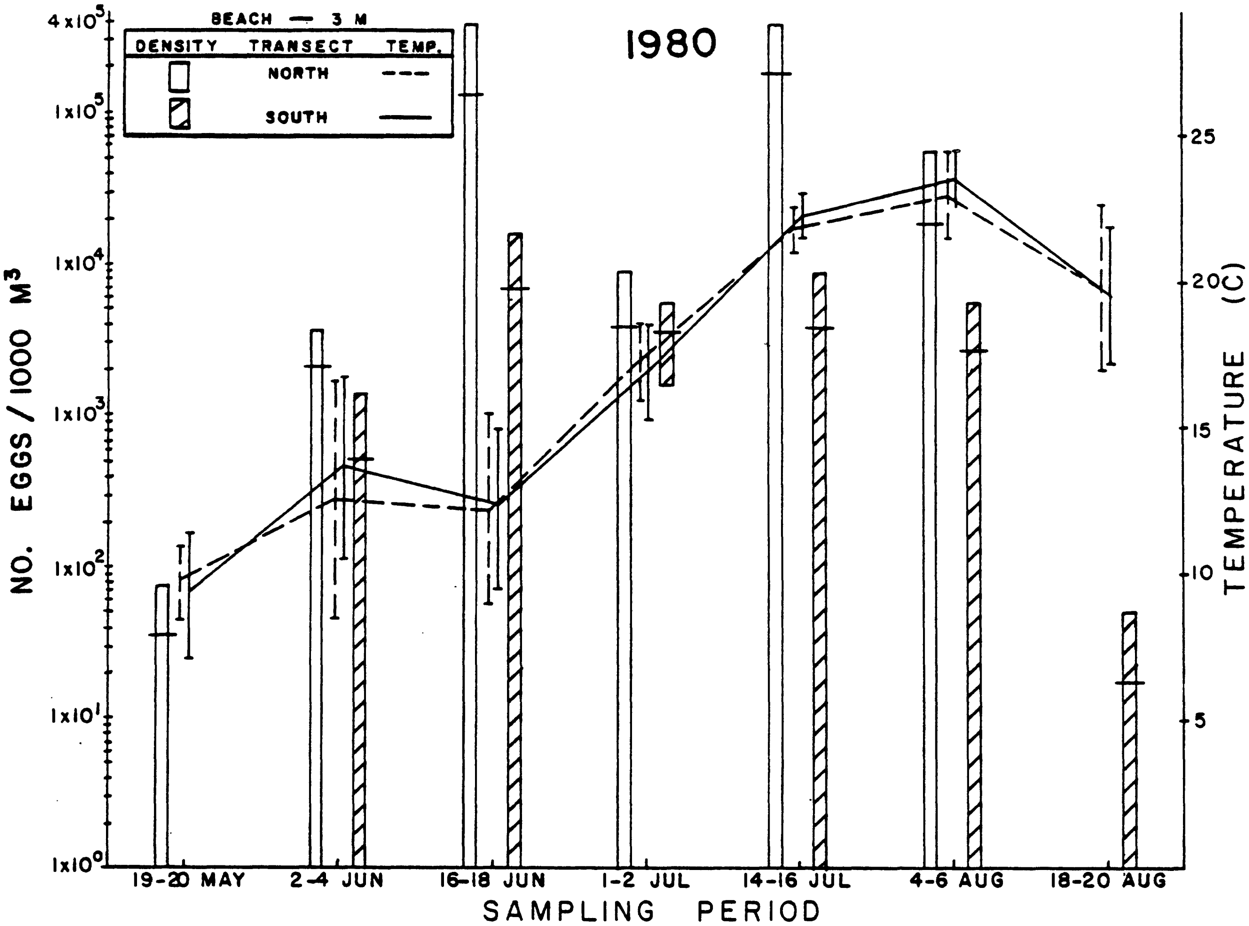


Fig. 98. Density (no./1000 m^3 plotted on log scale) of fish eggs collected during April to September 1980 at beach - 3 m (all contours, depth strata and diel periods pooled) near the J. H. Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S. E. Midpoint of water temperature range (vertical line) at time of collection is shown.

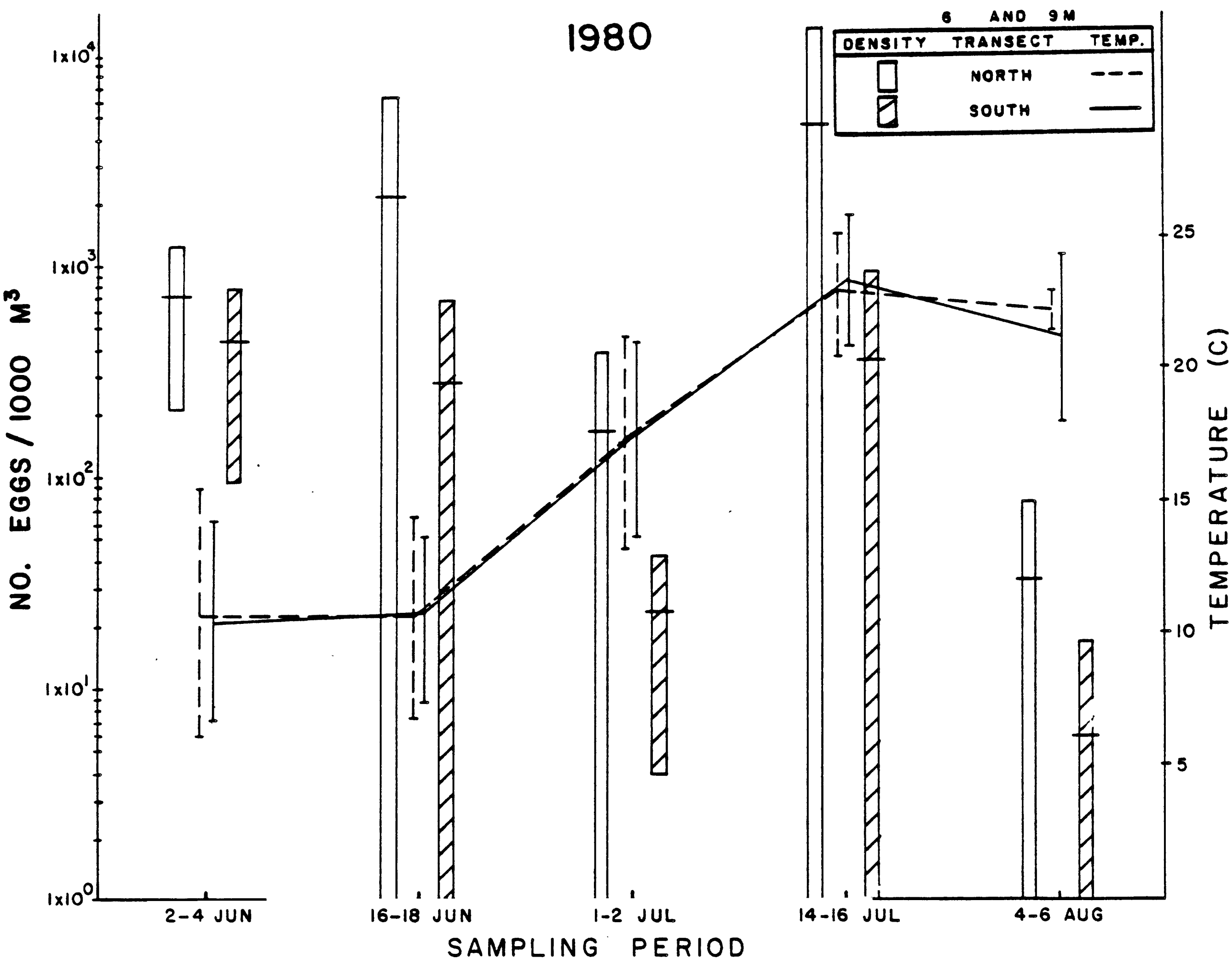


Fig. oo. Density (no./1000 m^3 plotted on log scale) of fish eggs collected during April to September 1980 at 6 and 9 m (all contours, depth strata and diel periods pooled) near the J. H. Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S. E. Midpoint of water temperature range (vertical line) at time of collection is shown.

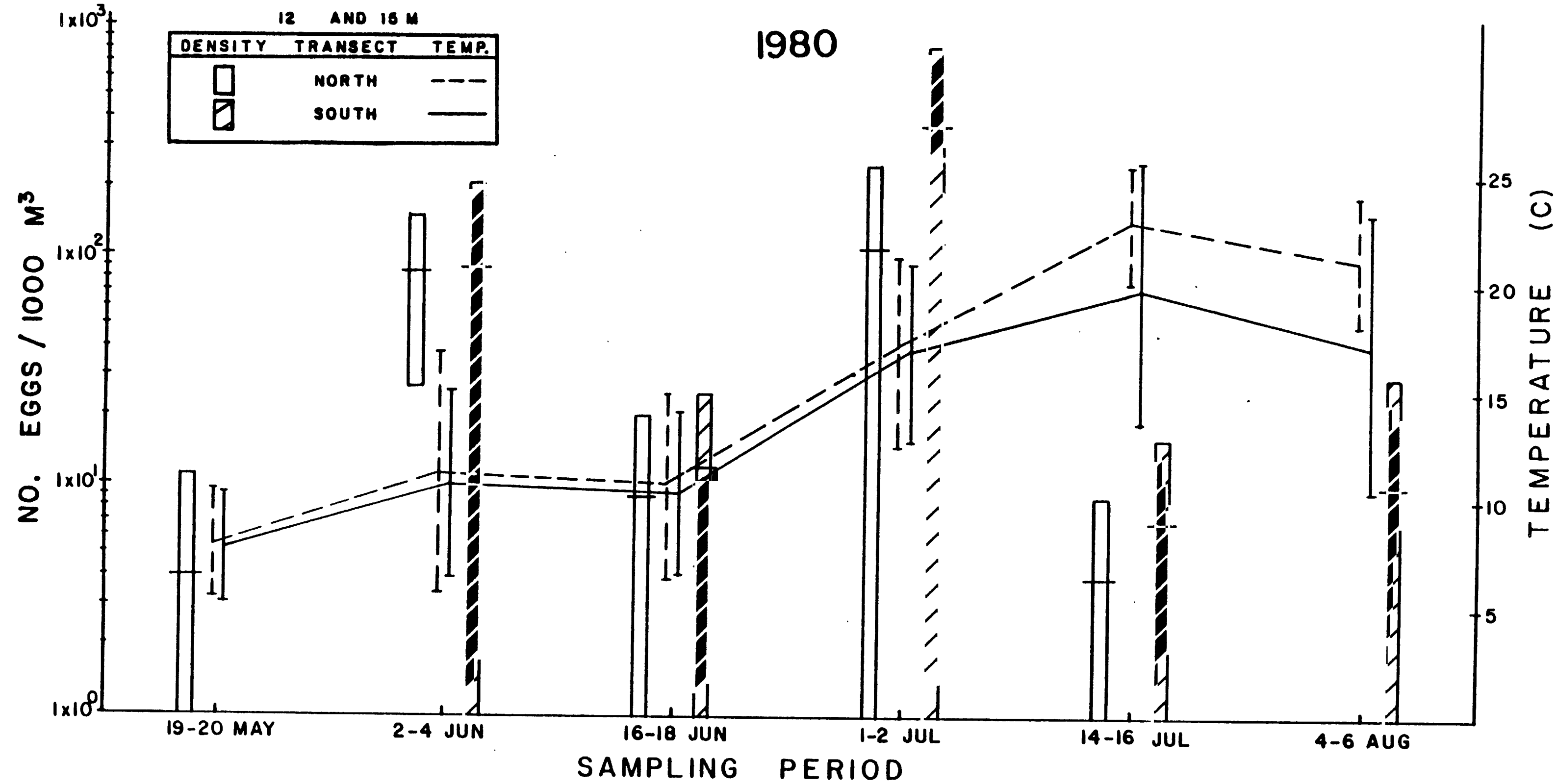


Fig. 100. Density (no./1000 m^3 plotted on log scale) of fish eggs collected during April to September 1980 at 12 and 15 m (all contours, depth strata and diel periods pooled) near the J. H. Campbell Plant, eastern Lake Michigan. Horizontal line across each bar denotes mean density while height of bar represents ± 2 S. E. Midpoint of water temperature range (vertical line) at time of collection is shown.

Late June--

Trends in mean egg densities in late June of any year closely paralleled trends in larval alewife abundance (see RESULTS AND DISCUSSION, Alewife, Larvae, Seasonal Distribution). During late June of the 4 yr sampled, highest mean fish egg densities were reported in 1979 and 1980 coincident with the highest reported late June larval alewife densities. Higher inshore water temperatures probably stimulated increased spawning activity in late June 1979, compared with early June of that year. Generally comparable early and late June water temperatures in 1980 allowed for increased spawning activity in late June of that year. Decreased fish egg densities in late June 1978 compared with early June of that year were probably caused by depressed nearshore water temperatures. The reason for continued low mean densities of fish eggs during late June 1977 despite generally increased water temperatures was lack of use of the benthic sled; plankton tows alone were unable to demonstrate trends in egg abundance.

As was found during early June, the highest mean densities of fish eggs were in the nearshore (beach - 3 m) area, with substantial declines with increased depths (Figs. 91-100). An extraordinarily high mean density of fish eggs ($1.05 \times 10^6/1000\ m^3$) was observed in late June 1979 at the south transect nearshore station group, which indicated that more substantial egg deposition had occurred in this area than during late June of any year at either transect.

Early July--

Considerable fish egg deposition was indicated in early July 1978-1980. Again, lack of sled tow samples in early July 1977 was the primary cause of low egg densities in our samples at this time. The upwelling in early July 1979 may have caused low mean egg density (175 eggs/1000 m^3) at the south transect; however, the north transect beach to 3-m stations seemed unaffected. Uninterrupted contribution of eggs from the discharge canal to the north transect stations even during times of upwelling may explain this.

In all years, mean densities of fish eggs at north transect stations in early July exceeded those of the south transect. The distribution of fish eggs in the study area continued to be primarily nearshore (beach - 3 m) at both transects in all years (Figs. 91-100).

Late July--

The level of spawning activity of alewives and spottail shiners in late July varied considerably from year to year. During these years, no correlation between water temperature and spottail shiner larvae, alewife larvae or egg abundances was observed. During late July 1977-1979, mean densities of larval alewives and spottail shiners (see RESULTS AND DISCUSSION, Alewife and Spottail Shiner, respectively) diminished compared with early July of these years, apparently in response to cold-water upwellings. Coincidentally during these years, densities of fish eggs were generally higher in the nearshore zone during late July compared with early July

(Figs. 91-100). As in early July of all years, north transect stations had higher mean densities of eggs compared with south transect stations. Additionally, eggs were primarily distributed at the beach to 3-m stations; however, densities at the 6- to 9-m stations of both transects in late July 1980 were the highest reported at this station grouping of all years or time periods. This may be related to eggs spawned in the discharge canal being pumped out to the 6-m contour by the offshore discharge, which began operation in December 1979. We are unsure, however, whether the discharge of eggs at the 6- and 9-m north station grouping would cause increased egg densities at south transect stations at this contour. Densities of larval spottail shiners exhibited similar trends: mean densities at the 6- and 9-m station grouping in 1977-1979 were less than 100 larvae/1000 m^3, while densities at these stations in 1980 often exceeded 100 larvae/1000 m^3. This may be supportive of the contention that eggs and larvae from the discharge canal are being transported offshore by the discharge system, or may simply indicate that there was increased spawning activity in the area of the 6- and 9-m station grouping compared with other years.

August and September--

The first sampling period of August in 1978-1980 showed continued spawning activity with mean densities of eggs exceeding 2500 eggs/1000 m^3 during all years at the beach-3-m station grouping. Again north transect egg densities exceeded south transect densities, and eggs were markedly more concentrated nearshore.

Later August sampling in 1978-1980 indicated that spawning activity had appreciably diminished in the area as mean densities greater than 20 eggs/1000 m^3 were not observed in any year. This trend continued into September, when no densities exceeding 5 eggs/1000 m^3 were observed in any year. Although these data might indicate very little spawning activity, presence of newly hatched larval alewives in September of 1979 (see RESULTS AND DISCUSSION, Alewife) indicates that spawning does occur to some degree in late August and September.

Plant Effects

A Wilcoxon signed ranks test combining data from 1977 to 1980 indicated that densities of fish eggs were very significantly higher at the north transect compared with south transect stations (α= less than .001). There are a number of possibilities which might explain the observation of higher egg densities at north transect stations. Foremost, our observations in the discharge canal lead us to believe that there are resident populations of fish which are able to spawn there successfully. We believe that eggs spawned in the discharge canal were a major component of the eggs in our samples taken at the north transect. This contention is, in part, supported by the higher densities of larvae found in samples from the 6- and 9-m contours when the discharge was moved offshore in 1980. There is also a possibility that the offshore warm-water discharge or associated riprap and current encouraged more spawning to occur in the area of the discharge canal, and thus more eggs were found there. This contention is supported by the fact that larval, juvenile

and adult spottail shiners were generally more abundant at the north transect; however, alewife abundances were not significantly different between transects.

SCUBA OBSERVATIONS

1977

Introduction--

SCUBA dives were performed in August 1977 prior to construction of the Unit 3 water intake system. Diving was conducted to evaluate the potential site for the presence of important spawning and nursery grounds. A complete description is given in Jude et al. (1978); a brief summary of findings will be repeated here.

Results--

SCUBA observations at each of the transects swum in the vicinity of the Campbell Plant on 9-10 August 1977 are summarized below in three categories: physical, limnological and biological.

Physical Observations--

(1) Bottom sediments in the vicinity of the transects swum consisted exclusively of sand, primarily fine-grained and of homogeneous size.

(2) In all instances, grain size of substrate increased with decreasing depth. A distinct transition zone (from fine to coarse sand) occurred at approximately the 7.5-m contour. Coarse sand and occasional pebbles extended from the 7.5- to the 6.0-m contour.

(3) A few areas of fine sand overlain by several millimeters of silt were encountered, primarily offshore from the 7.5-m contour. Silt was often concentrated in troughs of ripple marks.

(4) Substrate was entirely shifting-sand; rocks, gravel, clay and heavy silt were not encountered.

(5) Ripple marks at stations deeper than 7.5 m were generally small (2-5 cm trough-to-crest, 10-20 cm crest-to-crest and 30-60 cm long) and were not consistently developed from any specific direction. Larger and more pronounced ripple marks were observed from the 7.5-m contour shoreward.

(6) Bottom profile was flat and even; rises, depressions and sudden drop-offs were not encountered.

Limnological Observations--

(1) Slight variations (1-4 C) in water temperature were noted between locations. Highest water temperature recorded (25 C) was at the 5.2-m station in front of the jetties, and may have resulted from heated discharge water flowing south and being deflected offshore by the jetties. Vertical temperature stratification was not encountered.

(2) Secchi disc readings remained relatively constant ranging from 3.0 - 4.0 m. Generally, horizontal visibility along the bottom increased with decreasing depth as a function of increased light penetration. An exception occurred at the jetties (dive no. 3) where visibility increased from 2 m to 3 m despite increasing depth. No explanation of this occurrence was apparent.

(3) Suspended material was finely particulate in nature; composition of particulate matter was indiscernible to the unaided eye.

Biological Observations--

(1) Loose algae were not found.

(2) Macroscopic accumulations of periphyton were not observed except when an occasional large substrate (e.g., tree branch, rock, trash) was encountered.

(3) Small (2-10-cm diameter) clumps of loose aquatic plant material were infrequently observed. A consistent pattern of occurrence was not determined but clumps appeared to occur more frequently at deeper (6-12 m) stations. Composition of clumps appeared to be similar. One sample was collected and found to be primarily the aquatic vascular plant Myriophyllum sp. and associated algae.

(4) Several tree branches and one log were encountered at isolated locations.

(5) Small aggregates (1-cm thick - approximately one handful in volume) of organic debris were occasionally observed. Debris was composed primarily of unidentified decayed material and pieces of terrestrial vegetation. Material was concentrated in troughs of ripple marks. Organic debris and floc were more abundant offshore from the 7.5-m contour; very little was observed at shallow (6.0 m) stations.

(6) Thousands of snails (Valvata sp.) were seen on the bottom within the south reference transects (dives no. 2 and 7) between the 11.6- and 9.1-m contour. Density of snails was estimated to be 100-300/m^2. Large concentrations of snails were not observed at other stations; often none were seen.

(7) Other macroinvertebrates were not observed; however, pieces of sphaeriid and gastropod shells were abundant, concentrated in troughs of ripple marks.

(8) Young-of-the-year alewives (20-30 mm TL) were observed at many but not all locations. Numbers were estimated to range from 1 to $30/m^3$ for the water volume examined. Fish were most frequently seen in schools, although larger numbers of fish may simply have been more highly visible. During other underwater studies we have observed that YOY alewives tended to school together during daylight hours. Fish appeared to remain predominately within 2 m of bottom, but a few schools were noted higher in the water column.

(9) Other species of fish were not observed.

<u>1978-1979</u>

No SCUBA observations were made in Lake Michigan during 1978 or 1979. Efforts were directed at the intake canal of Units 1 and 2.

<u>1980</u>

Introduction--

The underwater observation program in 1980 was designed to facilitate monitoring of the J. H. Campbell Plant's Unit 3 intake structures and associated riprap areas. Observational methodologies have been devised to allow divers to qualitatively and quantitatively assess and describe physical and biological characteristics of the study area, both spatially and temporally, and explore the relationship of observed changes with operation of the power plant.

Discussion of visual observations will occur in the following format: sediment, turbidity, periphyton, loose algae, invertebrates (attached invertebrates, mollusks, and others), fish, eggs and other observations.

Results--

<u>Sediment</u>--Encroachment of sand onto the riprap area was observed in 1980. The layer of sand had increased from a trace (barely detectable) in July to about 1 mm by October. Dorr (unpublished data, Great Lakes Research Division) reported an average floc layer of 2-3 mm on the Cook Plant riprap near Bridgman, Michigan during 1974-1980.

Ripple marks were often observed in the sandy areas adjacent to the riprap and at the south reference station. Generation appeared to have occurred from the west, southwest or northwest. Ripple marks observed were small with wavelength less than 22 cm, amplitude less than 6 cm and length along crests less than 25 cm.

<u>Turbidity</u>--Visibility within the study area during any particular dive series varied little between the south reference station and the intake station. Secchi disc readings ranged from 1.5 to 3.5 m at the intake and

south reference station. There appeared to be no increased turbidity associated with the Unit 3 intake risers. The least turbid conditions were associated with periods of warmest water temperatures.

Periphyton and loose algae--One 5-cm diameter piece of riprap was collected from the intake area to analyze composition of periphyton. Twenty-six periphytic algal taxa were identified during sample analysis including 21 diatom taxa, 3 green algal taxa, and 2 blue-green algal taxa. The algal component of the periphyton analyzed was relatively depauperate and lack of the green alga *Cladophora* was noted. The riprap associated with the D. C. Cook Nuclear Plant located farther south in Lake Michigan is similar in location and composition to that of the Campbell Plant. Although Cook Plant riprap was placed in 1972, luxurious growths of *Cladophora* were not noted until summer 1975.

The Campbell Plant riprap was basically uncolonized and free of periphyton during 1980. In the upcoming years increased periphyton colonization on the Campbell Plant riprap is expected. Because of the intake manifold depth (11 m) at Campbell, potential for growth as luxuriant as that seen at the D. C. Cook Plant is diminished.

Small clumps (3-25-mm diameter) of loose algae were observed periodically at the south reference station and at the sand/riprap interface (densities ranged from zero to 4 clumps/m²). Large accumulations (i.e., masses or mats) of algae were not observed. Algae appeared to be the major constituent of most clumps. Macrophytes were not observed.

Invertebrates--Sphaerids (fingernail clams) were observed frequently at the south reference and intake reference stations. Live specimens were not encountered, probably because only the exposed surface of the bottom was examined, not the underlying strata. Winnell and Jude (1979) found that in 1978 *Sphaerium* spp. were numerous at 9-, 12- and 15-m depths, but were most abundant at 15 and 20 m in 1977. *Valvata* sp. (snail) were observed on the intake risers during August. The large interstices caused by the large size of the limestone comprising the riprap could contain many more unattached invertebrates but it was not physically possible to examine these areas. One Baetidae (mayfly) nymph was observed in July on the intake manifold riprap. No evidence of bryozoan or freshwater sponge colonies on the riprap was found. The attached invertebrate *Hydra* showed a notable increase during the period July through October 1980. *Hydra* were observed on the fine-mesh screens, the intake risers, and on the riprap. Although *Hydra* did not clog up screen openings, the potential for biofouling by *Hydra* exists. Colony height reached 1.5 mm by October. Lack of any heavy algal growth may facilitate the growth of *Hydra*. Dorr (unpublished data, Great Lakes Research Division) reported that heavy algal growth precluded the growth of attached invertebrates at the D. C. Cook Plant; *Hydra* were observed in large numbers on sides and undersides of rocks where algal growth was reduced.

Fish eggs--Slimy sculpin eggs were collected from the riprap of the intake line during preliminary dives in June. These eggs were in an advanced stage of embryonic development and hatching began within 15 min of collection.

These eggs were collected from small, 2-5-cm diameter riprap. The present riprap overlies this smaller-sized stone, and should provide good nesting sites for slimy sculpins. Fish eggs were observed on the sand at the south reference station in July and August. They were most likely alewife eggs and were not viable (decomposition was beginning). During July, fish eggs were also observed at the sand/riprap interface near the intake manifold. Densities were low (3-5/m²). During a non-project dive in December lake trout eggs were collected from the intake line riprap in 9 m of water. Several were in the early stage of embryonic development.

Based upon these observations, the riprap substrate should provide good spawning and incubating habitat for demersal spawners such as slimy sculpin, johnny darter, lake trout and yellow perch.

Fish--Nine species of fish were observed during the study period (July-October 1980) and listed in descending frequency of sightings (measured as presence or absence, not as numbers of fish) during dives were: alewife, johnny darter, yellow perch, spottail shiner, trout-perch, slimy sculpin, ninespine stickleback, mottled sculpin and burbot. Lake trout were observed during December (non-project) dives. Multiple sightings of all species, except burbot and mottled sculpin, often occurred during a dive; usually less than five were seen. YOY alewives and adult spottails were often seen in schools (alewife 20-250, spottail 10-30). Schools of YOY alewives were observed in September and adult spottails in July. Seasonal occurrence and abundance of adult and juvenile alewives and spottail shiners in field catches were coincident with diver observations.

More fish species and greater numbers were observed at night than during the day. Fish abundance and species diversity was highest in July and August; seven of the nine species encountered during the study were observed in July and August. Number of fish observed was highest in August due to the large schools of YOY alewives. Very few fish were observed during October. Yellow perch were more active during the day, but rested on the riprap at night and could be easily grasped. Sculpins were more active and visible at night coming out of the rock interstices to rest on the riprap. During a preliminary dive in June large numbers of sculpins (10 per m²) were observed guarding nests on the smaller (2-5-cm diameter) riprap which underlies the present strata of large (1-2.5-m diameter) riprap, which will make observations of fish very difficult in the future because of the cryptozoic nature of slimy sculpins. Although yellow perch spawning was not observed in 1980, (spawning was probably completed before SCUBA observations began) perch most likely will use the riprap as a spawning substrate. Johnny darters were more active during the day than night but were more alert than yellow perch at night. Schooling was observed for alewives and spottail shiners; sculpins and johnny darters were randomly distributed.

Numbers of fish observed were much higher in the riprap area of the intake manifold than either sand substrate reference area. Dorr and Jude (1980) reported similar observations at the D. C. Cook Plant. Only one johnny darter

was observed at the reference station south of the plant. Spottails, trout-perch, and smelt were observed at the reference area adjacent to the intake manifold, all at night.

Other observations--During July and August large numbers of dead and live adult alewives were observed inside the intake risers. These fish were obviously residents of the discharge and intake channel. They apparently swam through the intake line into the risers; quillbacks and spottails were also observed. Dives in the intake channel revealed a large population of adult alewives was present. They were observed orienting themselves against the flow from the intake pipe, apparently feeding. Alewives were observed well into the intake line.

Summary and Conclusions--

Twelve dives were performed during the period July-October 1980: three during each month. Both sand and riprap substrates were examined. The sand and floc covering the riprap was about 1 mm thick by the end of October. Periphyton growth was sparse with a notable absence of *Cladophora*. Disturbance of the area due to construction activity (mechanical scour) and the 11-m depth probably limited *Cladophora* growth. Sphaeriid shells were frequently observed on the sand substrate, but not on the riprap. Unattached invertebrates were rarely observed in the riprap area. The attached invertebrate *Hydra* became increasingly abundant during the study period. They were most noticeable on the intake risers and screens. Alewife, spottail shiner, slimy sculpin and lake trout eggs were observed on the riprap in 1980. Nine species of fish were observed during the study period. Listed in descending order of frequency of observation they were: alewife, johnny darter, yellow perch, spottail shiner, trout-perch, ninespine stickleback, slimy sculpin, mottled sculpin and burbot. Lake trout were observed during December (non-project dive). Young-of-the-year alewives were abundant during September. They occupied the upper one third of the water column over the intake manifold. Large numbers of slimy sculpins were observed nesting on the riprap during preliminary dives in June, but dumping of additional (larger) riprap over nesting sites most likely decreased successful incubation of their eggs. Numbers, species diversity and activity of fish were highest at night and were much higher in the riprap area than in sand substrate areas. Seasonal abundance of alewives and spottail shiners, as determined from diver observations, coincided with field collections of these species. Due to construction activities this study did not begin until July and therefore complete seasonal trends in biological activity and abundance could not be documented by diver observations. A more intense sampling effort will be undertaken during 1981. Observations will be made from April to November and a complete pattern of biological activity will be documented.

In conclusion, compared with the surrounding inshore zone of the lake (15 m or less), the riprap area has created an atypical, more diverse and more sheltered habitat which attracts fish and other biota. The riprap area is now in its early successional stages. With the passage of time, this area should exhibit increased species diversity and abundance.

SUMMARY AND CONCLUSIONS

INTRODUCTION

This report summarizes 4 yr of preoperational fishery data for Lake Michigan, with emphasis on the last year, 1980, which had not yet been discussed in detail as had the previous 3-yr, 1977-1979. It was our intent to document the variability in the spatial and temporal distribution of larval, juvenile and adult fish near the J. H. Campbell Plant, eastern Lake Michigan. Data from the 4-yr study were examined for each life stage for each species. A description of spawning times, nursery areas and location of concentrations of each appropriate age-group was made. Catch differences between transects, among depth contours and years as well as whether plant operation has affected the abundance of fish species were elucidated. We prepared distribution graphs, length-frequency histograms, water temperature plots, statistical test data and summarized our findings in preoperational years. These data sets and conclusions will eventually be used as background data to evaluate any effects of 1 full year of operation of Unit 3 on the Lake Michigan ecosystem, particularly as it relates to fish.

TOTAL CATCH

During our 4-yr study, 48 species of fish representing 17 families, were collected or observed in Lake Michigan near the J. H. Campbell Plant. They included a wide range of species, including marine forms (alewife, smelt, salmon, sea lamprey), a threatened species (lake sturgeon), sport fish (yellow perch, trout), commercial fish (bloaters, lake whitefish) and forage species.

The yearly catch of juvenile and adult fish during 1977-1980 was dominated by alewives in 1977 (69%) and 1978 (49%), while rainbow smelt assumed dominance in 1979 (38%) and 1980 (44%). Alewives were the second-most abundant fish caught in 1979-1980.

Large alewife fluctuations were attributed to YOY abundance changes over the years; the adult catch has remained relatively stable over the 4 yr. Rainbow smelt produced strong year classes in 1979 and 1980, which contributed to the large trawl catches of YOY and yearlings observed in these years. Spottail shiner catch was relatively stable over the 4 yr ranging from 10% of the total catch in 1977 (not a full year of sampling) to 18% in 1980. They were the third-most common fish collected in Lake Michigan.

Trout-perch were the fourth- or fifth-most common species collected during the study years, with 1980 being the year of maximum catch. This year was marked by a strong yearling age-group and good survival of adults from 1979.

Yellow perch comprised between 1 and 2% of the total catch each year, usually ranking sixth in abundance (fourth in 1977). Large year classes were produced in 1977 and 1980, while cold inshore water temperatures in 1979, due to frequent upwellings and cold air temperatures, caused depressed yellow perch catches.

The catch of unidentified Coregoninae, believed to be mostly bloaters, rose dramatically during the course of the study from 1% of the catch in 1977 to 11% in 1980. They rose from the sixth-most often caught fish to fourth. The increase is a lake-wide occurrence attributed to banning of commercial harvest by gill nets and a decline or at least stabilization in alewife populations.

A number of lesser-caught species, such as lake trout, carp and gizzard shad, exhibited some catch differences over the 4-yr period. Lake trout were caught in much higher numbers during 1980 (after the newly laid riprap for the Unit 3 intake was in place) than in previous years. However, lake trout were abundant at both plant and reference stations. Slimy sculpins and johnny darters (which are known to be attracted to riprap) and carp and gizzard shad (documented as being attracted to thermal plumes), were not collected in larger numbers in the vicinity of the plant.

Of the four gear types used for collecting juvenile and adult fish (trawls, surface and bottom gill nets and seines), trawls collected the vast majority of fish. Surface gill nets caught the least number of fish. This gear was the only gear that fished directly in the thermal plume.

ALEWIFE

Alewife was the most abundant species in our catches during 1977-1978 and second in abundance in 1979-1980 (Table 55). Alewife larvae are the most abundant larval fish during most of late spring and summer. Larval fish abundance is strongly linked to favorable water temperatures; during 1979, a year of frequent upwellings, alewife larvae catches were considerably reduced. Statistical testing of larval fish densities pooled over the 4 yr showed no significant differences existed between the reference and plant-influenced transects. Examination of alewife density data for differences between transects revealed that in 1978 more alewives were collected at the south reference transect, in 1980 more were observed at the north transect and for 1977 and 1979 no differences in larval density between transects were found. Because of the yearly variability in preoperational alewife larvae densities, a single year comparison in 1981 probably will be inconclusive. For trawl catches of juvenile and adult alewives, no significant differences between transects were detected.

Highest entrainment of alewife larvae will clearly occur during peak alewife hatching times, usually July. During years of extensive upwellings these peaks could be delayed until August.

RAINBOW SMELT

Rainbow smelt was the dominant species in our 1979-1980 catches. Many YOY and yearlings were present in our trawl catches during these latter years of our study. Smelt are an introduced marine species. Adults spawn in the spring and then move offshore, returning inshore only during upwellings (Table 56). YOY inhabit the inshore zone during most of the summer and fall, while yearlings are present during spring and early summer. Densities of smelt

Table 55. Summary of the abundance, distribution and temperature-catch relationships for larval, juvenile and adult alewife collected during 1977-1980 in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan.

Life Stage	Seasonal Distribution	Spatial Distribution	Temperature-Catch Relationships	Prevalent Length Groups (mm)	Relative Abundance
Larvae	May to Sep; most common in Jul and Aug.	1-15-m contours; found in all depth strata. During upwellings confined to 0-6-m contours.	Newly hatched larvae generally most abundant at 15-23 C, but found as low as 4 C.	May 3.5-4.0; Jun 3.5-8.0; Jul 3.5-25.4; Aug 3.5-25.4; Sep 4.0-25.4.	very abundant
YOY	Jul-Dec; most common Aug-Oct.	Jul-Aug, almost exclusively 0-3-m contours. Sep 0-9 m, Oct-Nov 0-15 m, Dec 6-15 m.	10-20 C, primarily; but found at almost all temperatures sampled.	Jul 10-50; Aug 10-80; Sep 20-100; Oct 20-110; Nov 20-130; Dec 40-100.	abundant
Yearling	Apr (only in 1980)-Sep; usually May-Sep.	April (1980) 6-15-m contours; May-Sep mostly 0-9 m. More pelagic than adults.	10-16 C.	Apr 60-90; May 60-130; Jun 60-130; Jul 50-140; Aug 50-150; Sep 70-150.	common to uncommon
Adult	Apr-Nov; most abundant Jun-Jul. They spawn in Jun-Aug.	0-15-m contours; most abundant at depth contours to 9 m during Jun-Aug.	10-16 C.	Apr 130-200; May 140-230; Jun 120-240; Jul 120-250; Aug 120-210; Sep 140-230; Oct-Nov (few) 160-200.	abundant

larvae were low compared to other major species in the area. A statistically significant catch difference (more caught at plant transect stations) between transects was documented for larval smelt in 1979-1980. Since rocky substrate from construction of the offshore intake and discharge system existed during 1979 and 1980 from near shore to 11 m, smelt were thought to have spawned there. Survival rates were also expected to be higher in this habitat, thus contributing to the higher larval densities recorded there.

Adult and juvenile trawl catch statistical analyses revealed no significant catch differences in 1977 between transects; however, in 1978-1980 significantly more smelt were consistently taken in the vicinity of the plant along the north transect.

Trawl catches were comprised of mostly YOY and yearlings, which were present in higher abundances in the plant area. Construction of the intake structures during 1979-1980 corresponded with years of maximum catch differences. In 1978, when no intense disruption of the study area by construction activities occurred, catches were similar between transects. Increased food supply, the riprap or currents in the vicinity of the plant apparently attract YOY and yearling smelt.

SPOTTAIL SHINER

Spottail shiners are benthic minnows commonly found in the vicinity of the Campbell Plant. They were consistently the third-most abundant fish in our catches, being caught during every month sampling was conducted. Spottails migrate shoreward from deep water starting in April and May, spawn during June and July and remain inshore, usually in the beach zone to 9 m of water, until late fall when they migrate offshore (Table 57). Larval spottails are abundant in the beach zone to 3 m where most spawning occurs. YOY migrate to deep water in October. Spottails feed on benthic organisms, but are seldom eaten by piscivorous fish in our study area.

Timing of construction activity in Lake Michigan was correlated with statistical differences in catches noted for larval, juvenile and adult fish, making definitive statements about plant effects difficult. In 1977, when the thermal discharge from Units 1 and 2 was onshore, no catch differences between transects were noted for larval or adult fish. From 1979-1980 however, coincident with initiation and near completion of intake and discharge structure construction in Lake Michigan, larval, juvenile and adult fish were statistically more abundant in the vicinity of the plant. Reasons for the increased abundance of all age-groups of spottails at the plant transect are not clear; however, increased food supply, because of bottom disruptions in the area and increased spawning substrate provided by the riprap (which extended all the way to shore) are two possible causes.

Entrainment of larval spottails during future years is expected to be limited to fish which spawn on the riprap in the vicinity of the intakes. To date, the overwhelming majority of spawning occurs in the nearshore (beach to 3 m) zone, where larvae were most abundant. Since YOY spottails are generally demersal and most often found inshore, they probably will not come in contact

Table 56. Summary of the abundance, distribution and temperature-catch relationships for larval, juvenile and adult rainbow smelt collected during 1977-1980 in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan.

Life Stage	Seasonal Distribution	Spatial Distribution	Temperature-Catch Relationships	Prevalent Length Groups (mm)	Relative Abundance
Larvae	May-Aug; most common in May or Jun.	1-15-m contours; most common at 6-15 m; found in all strata, but scarce near surface.	7-24 C; most common at 11-16 C.	May 4-10; Jun 5-20; Jul 4.1-25.4; Aug 12-25.4.	common
YOY	Jul-Dec; most abundant in Aug.	6-15-m contours; most abundant at 9-12 m.	1-25 C; most common at 12-16 C.	Jul 25.4-38; Aug 26-54; Sep 25-64; Oct-Dec 30-100.	abundant
Yearling	Apr-Dec; most abundant in May.	1-15-m contours; most common at 6-15 m.	1-25 C; most common at 4-12 C.	Apr-May 40-114; Jun 45-124; Jul 50-130; Aug-Dec 60-160.	abundant
Adult	Apr-Dec; most abundant in Apr; spawning in Apr and May.	1-15-m contours; most common at 6 m.	1-21 C; most common at 6-14 C.	Apr-Dec 110-260.	common

Table 57. Summary of the abundance, distribution and temperature-catch relationships for larval, juvenile and adult spottail shiner collected during 1977-1980 in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan.

Life Stage	Seasonal Distribution	Spatial Distribution	Temperature-Catch Relationships	Prevalent Length Groups (mm)	Relative Abundance
Larvae	May-Sep; most common in Jul and Aug.	1-15-m contours; most common at 1-3 m at all strata.	8-23.5 C; most common at 15-23.5 C.	May 5.0-5.6; Jun 4.0-5.6; Jul 4.8-11.7; Aug 4.3-15.3; Sep 15-23.5.	very common
YOY	Mid Aug-Dec; most abundant in Sep.	1-15-m contours; most common at 1-6 m.	4.0-25.7 C; most common at 15.6-25.7 C.	Aug 25.4-58; Sep 26-64; Oct 26-70; Nov-Dec 26-75.	common
Yearling	Apr-Jul; sizes overlap with adult fish after Jul.	1-15-m contours; most common at 1-3 m.	4.0-25.7 C; most common at 11-23 C.	Apr 28-75; May 31-75; Jun 40-75; Jul 48-75.	common
Adult	Apr-Dec; most abundant in Jul. They spawn in Jun-Jul.	1-15-m contours; most common at 1-6 m.	4.0-25.7 C; most common at 11-23 C.	Apr-May 76-154; Jun-Jul 76-140; Aug-Oct 76-148; Nov-Dec 75-140.	abundant

with the Unit 3 intake screens, which are situated off the bottom in 11-m water. However, some movement off bottom was documented for juveniles and adults, as between 0.1 and 9.8% of surface gill net catches during 1977-1980 was comprised of spottails. In addition, spottails may be vulnerable in the fall during seasonal movements offshore.

TROUT-PERCH

Trout-perch was the fourth-most abundant species collected during the 4-yr study period comprising from 1 to 3% of the total catch. They are a demersal species, which reach a length of 160 mm. They feed primarily on benthos and are seldom fed on by piscivorous fish in the study area. Trout-perch have an extended spawning period from April through August (Table 58). Most fish were caught by trawls. Trout-perch were caught mainly at night and they exhibited a diel horizontal movement toward shore during the night and back to deeper water during the day. We have not collected large numbers of trout-perch larvae because we believe so few adults spawn during a given month that their larvae are never very abundant. Entrainment potential of trout-perch is expected to be negligible because of their demersal habit. We statistically compared the juvenile and adult catches between the reference and plant transect 6-m stations in 1977 and found no significant difference. In 1978-1980, a significantly greater catch was registered at the plant transect station L (6 m, north) compared with reference station C. One year (1979), contributed to the significant AREA and YEAR X AREA interaction. During 1979, maximum construction activity on the new intake system in Lake Michigan was transpiring. Food stirred into the water column or decreased net avoidance may have caused the higher catch at plant transect stations. Trout-perch larvae data also suggest that the riprap may be attracting spawning trout-perch as almost two-thirds of the 44 larvae caught during the 4-yr study were taken in 1980, the first year the riprap area was completed during the trout-perch spawning season.

YELLOW PERCH

Yellow perch are one of the important sport fish in our Lake Michigan catches. They comprised from 1 to 2% of the catch, usually ranking sixth in abundance. Yellow perch are offshore during the winter, migrate inshore during spring and usually spawn sometime in late May or early June (Table 59). Exact spawning areas are unknown in the Campbell vicinity. Some spawning may occur on the jetties and on the newly laid riprap, as these types of areas appear to be optimal habitat. Larval perch are not common in our collections, but do occur in modest densities during June. They quickly grow to a size (around 10 mm) where they avoid all our sampling gear, until late July-August when many YOY are seined in the beach zone. In the fall perch migrate offshore.

Catches of yellow perch during the 4-yr study varied considerably depending on water temperatures in the study area. During 1979, a year of frequent upwellings of cold water, yellow perch apparently sought warmer temperatures elsewhere, thus depressing total catch for that year. Statistical evaluations of juvenile and adult catch data showed no significant

Table 58. Summary of the abundance, distribution and temperature-catch relationships for larval, juvenile and adult trout-perch collected during 1977-1980 in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan.

Life Stage	Seasonal Distribution	Spatial Distribution	Temperature-Catch Relationships	Prevalent Length Groups (mm)	Relative Abundance
Larvae	Apr-Sep; relatively uncommon in vicinity of plant. Most common Jul-Sep.	beach-15-m contours; most common at 6-15 m. Most collected in sleds.	3-24 C; most common at 12-22 C.	Apr-Sep 5.7-20.	rare (most collected in 1980)
YOY	Aug-Nov; relatively uncommon in sampling.	6-15-m contours; most common at 9-15 m.	5.0-22.0 C.	Aug-Nov 15-44.	rare
Yearling	Apr-Dec; during spring through fall migration inshore during night and back to deeper water during day. Relatively high catches May-Aug; peak abundance in Jul.	beach-15-m contours; most common between 6-12 m.	4-26 C; most common at 4-22 C. In 1977 preference for cooler water noted.	May 15-54; Jun 25-64; Jul 25-74; Aug 35-84; Sep 45-94; Oct 65-94; Nov-Dec 75-104.	common
Adult	Apr-Dec; highest catch usually in May (inshore spawning migration). High spawning activity May-Aug with peak in Jun, but spawning may occur Apr-Sep.	beach-15-m contours; most common between 6-12 m.	4-26 C; most common at 4-22 C.	May 65-164; Jun >65; Jul >65; Aug-Sep 75-164; Oct-Dec 85-174.	common

Table 59. Summary of the abundance, distribution and temperature-catch relationships for larval, juvenile and adult yellow perch collected during 1977-1980 in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan.

Life Stage	Seasonal Distribution	Spatial Distribution	Temperature-Catch Relationships	Prevalent Length Groups (mm)	Relative Abundance
Larvae	May-Aug; most common in May and Jun.	beach-15-m contours; most common at beach-3 m.	3-28 C; most common at 7-14 C.	May 5.7-7.2; Jun 4.0-9.5; Jul 4.2-10.5; Aug 6.0-8.6.	common
YOY	Jul-Dec; most common in Sep.	beach-15-m contours; most common at beach-9 m.	1-22.5 C; most common at 11-19 C.	Jul 25-44; Aug 25-64; Sep 25-94; Oct-Dec 35-104.	common
Yearling	Apr-Dec; most common in Jul-Sep.	beach-15-m contours; most common at beach-9 m.	2.4-23.9 C; most common at 8-20 C.	Apr 55-94; May 25-114; Jun 45-114; Jul 45-124; Aug 95-134; Sep 95-164; Oct-Dec 105-154.	common
Adult	Apr-Dec; most common in Jun-Sep. Peak spawning in Jun.	beach-15-m contours; most common at beach-9 m.	1.0-22.5 C; most common at 7-21 C.	Apr 145-264; May 115-264; Jun 95-334; Jul 105-314; Aug 115-334; Sep 125-334; Oct-Dec 135-344.	common

differences between transects in 1977 and 1978. In 1979 more fish were caught at the north transect; however, as noted, 1979 was a year of low catches and the low sample size at 6-m stations decreased the validity of inferences about results. In 1980, more fish were caught at the south reference transect. Again, catch differences between transects for 1980 were not consistent and one spurious high catch in September was thought responsible for the significant catch difference result. Therefore, it was our belief that no valid and consistent differences in catch were present for yellow perch. A similar finding was rendered for larvae; no overall catch difference was apparent between transects. However, more were collected in June 1979 at the north (plant) transect. Depending on the extent spawning perch use the riprap, we may see consistently higher numbers in these areas in future years. Entrainment potential for yellow perch could be high as a result, since newly hatched larval perch (5-6 mm) move passively with water masses. Once they reach about 10 mm (growing at a rate of about 0.1 mm/day), they are very mobile and we rarely collect them in plankton nets. Depending on how these larger larvae react behaviorally to the intake screens, even perch this size have the potential to be entrained, for example, if they perceive the structures as escape or concealment habitat.

UNIDENTIFIED COREGONINAE

Members of the subfamily Coregoninae are very difficult to separate consistently; therefore, we use the subfamily designation. Most are believed to be bloaters. Members of this group were part of the historical complex of whitefish species, which inhabited all parts of the lake. With invasion of the sea lamprey, overfishing and introduction of exotic species, most members of the "chub complex" became extinct. The bloater is one species, the smallest in size, which has survived the upheaval in low numbers. Recently, due to banning of commercial harvest with gill nets and a long term decline and stabilization in alewife populations, this group is expanding. They went from 460 in our collections in 1977 to 8934 in 1980. We sample only the fringes of this offshore population (they prefer cold water) and most fish collected have been YOY and yearlings. Bloaters are inhabitants of the deep basins of Lake Michigan and they are only found inshore during upwellings (Table 60). They also spawn in very deep water during winter (72-108 m), but we have collected some of their larvae inshore. Bloaters feed on benthos and zooplankton and traditionally were the mainstay of lake trout diets. We have not found any fish we could identify as bloaters in the stomachs of piscivorous fish collected to date.

Larval bloaters were collected in highest numbers during 1980 (49), while combined catch for 1977-1979 was only 11 larvae. These were too few fish for definitive statements, but larval densities on the south transect were twice those of the north in the beach zone during April, the month of highest catch in 1980. For juveniles and adults, trawl catches in 1978-1980 on the north transect were statistically greater than those on the south transect. This difference was most pronounced during 1979 when construction activity in Lake Michigan was at its peak. Increased turbidity may have decreased net

Table 60. Summary of the abundance, distribution and temperature-catch relationships for larval, juvenile and adult unidentified Coregoninae collected during 1977-1980 in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan.

Life Stage	Seasonal Distribution	Spatial Distribution	Temperature-Catch Relationships	Prevalent Length Groups (mm)	Relative Abundance
Larvae *	Apr and May.	1-3-m contours.	4.4-13.8 C.	14-24.	rare
Larvae #	Jun-Aug.	3-15 m; most common 6-15 m; at all strata, scarce near surface.	12.2-25.1 C.	11-14.5.	very rare
YOY	Sep-Dec; most common in Oct and Nov.	Beach-15 m; most common at 6-12 m.	1-23 C; most common at 5-17 C.	Sep 62-74; Oct 65-78; Nov 65-84; Dec 64-89.	common
Yearling	Jun-Sep; most common in Jun and Jul.	6-15 m; most common at 6-9 m.	3-23 C; most common at 3-21 C.	Jun 90-104; Jul 100-124; Aug 110-125; Sep 125-150.	common
Adult	Jun-Sep; most common in Jun and Jul. Spawn winter to early spring.	6-15 m, in bottom strata.	3-23 C; most common at 6-19 C.	Jun-Sep 160-310.	uncommon but increasing in abundance since 1977

* Believed to be *Coregonus clupeaformis* or *C. artedii*.
# Believed to be *C. hoyi*.

avoidance leading to the higher catch or increased densities of suspended food organisms in the water column may have attracted fish. Most fish trawled were YOY and yearlings.

FISH EGGS

Collection of large numbers of fish eggs in the inshore zone of Lake Michigan emphasizes the importance of this area as nursery grounds. Most eggs we believe to be those of alewife and spottail shiner, but a number of other species are not precluded. Other species, such as sculpin and johnny darter, lay their eggs on the undersides of rocks and only SCUBA observations confirmed their presence. Yellow perch egg masses are also suspected to be laid in areas of rocks that we cannot sample with our standard gear. The benthic sled was the most efficient gear for sampling eggs. June was the first month when high densities of fish eggs occurred; maximum densities occurred in late June. September was the last month in which eggs were observed. However, lake trout eggs were discovered by SCUBA divers in November. Highest densities of eggs were found in the beach to 3-m zone, with diminished quantities farther offshore. Considerably more eggs were found at the plant transect than at the reference area during 1977-1980. Source of these significantly higher quantities of eggs are thought to be the onshore and offshore discharge of eggs spawned in the intake and discharge canals. Undoubtedly, the offshore discharge of warm water, currents and riprap encouraged spawning in the vicinity of the plant in 1980.

SCUBA OBSERVATIONS

Underwater observations of the Unit 3 intake and discharge area during 1980 were designed to qualitatively and quantitatively assess the physical and biological characteristics of the area. We also assessed how the wedge-wire screens and their associated structures and riprap were used by the ecological community, monitored colonization of the screens by algae and invertebrates and documented what fish frequented the area for cover, food and spawning. We found that sand had encroached onto the riprap area in 1980. Regarding visibility (water clarity), no differences between transects were observed. A rock examined for periphyton contained 26 species of diatoms, 3 species of green algae and 2 species of blue-green algae. No *Cladophora* was observed, which was unexpected, since *Cladophora* is a common green alga which attaches itself to plant intakes, breakwaters and other solid objects in the photic zone of Lake Michigan. The riprap was newly laid in 1979 and early 1980, and we found that it was basically uncolonized and free of extensive periphytic growth. Fingernail clam shells were frequently observed at both transects, and a snail (*Valvata* sp.) was observed on the intake risers in August. *Hydra*, a coelenterate, showed an increase over the period July-October 1980. They were found on the wedge-wire screens, intake risers and riprap. Slimy sculpin eggs were collected from the riprap in June, while suspected alewife eggs were found on the sand at the reference station in July-August. Lake trout eggs were collected from the riprap in December 1980. Nine species of fish were observed during the study including: alewife, johnny darter, yellow perch, spottail shiner, trout-perch, slimy sculpin, ninespine stickleback, mottled sculpin and burbot. Lake trout were seen in November. Higher abundance and

diversity of fish were observed at night. More fish were on the riprap than at comparable sandy areas on the south transect, demonstrating the well known fact that fish are attracted to these rocky areas. During July-August, many dead and live alewives along with with live spottails and quillbacks were observed within the intake risers. These fish are believed to be residents of the intake canal.

LITERATURE CITED

Amundrud, J. R., D. J. Faber and A. Keast. 1974. Seasonal succession of free-swimming perciform larvae in Lake Opinicon, Ontario. J. Fish. Res. Board Can. 31:1661-1665.

Anderson, R. C. and D. Brazo. 1978. Abundance, feeding habits and degree of segregation of the spottail shiner (Notropis hudsonius) and longnose dace (Rhinichthys cataractae) in a Lake Michigan surge-zone near Ludington, Michigan. Mich. Acad. 10:337-346.

Armstrong, J. W., C. R. Liston, P. I. Tack and R. C. Anderson. 1977. Age, growth, maturity and seasonal food habits of round whitefish, Prosopium cylindraceum, in Lake Michigan near Ludington, Michigan. Trans. Amer. Fish. Soc. 106:151-155.

Becker, G. C. 1976. Environmental status of the Lake Michigan region. Vol. 17. Inland fishes of the Lake Michigan drainage basin. Environ. Cont. Techn. Earth Sci. Argonne Nat. Lab., Argonne, Ill. 237 pp.

Bigelow, H. B. and W. C. Schroeder. 1963. Family Osmeridae. pp. 533-597. In: Fishes of the western North Atlantic. Mem. Sears Found. Mar. Res. 1(3):630 pp.

Bodola, A. 1966. Life history of the gizzard shad, Dorosoma cepedianum (LeSueur), in western Lake Erie. U. S. Fish Wildl. Serv. Fish. Bull. 65:391-425.

Bowen, A. J. and D. I. Inman. 1969. Rip currents. 2. Laboratory and field observations. J. Geophys. Res. 74:5479-5490.

Brandt, S. B. 1980. Spatial segregation of adult and young-of-the-year alewives across a thermocline in Lake Michigan. Trans. Amer. Fish. Soc. 109:469-478.

_____, J. J. Magnuson and L. B. Crowder. 1980. Thermal habitat partitioning by fishes in Lake Michigan. Can. J. Fish. Aquat. Sci. 37:1557-1564.

Brazo, D. C., P. I. Tack and C. R. Liston. 1975. Age, growth and fecundity of yellow perch (Perca flavescens), in Lake Michigan near Ludington, Michigan. Trans. Amer. Fish. Soc. 104:726-730.

Brown, C. J. D. and R. J. Graham. 1954. Observations on the longnose sucker in Yellowstone Lake. Trans. Amer. Fish. Soc. 83:38-46.

Brown, E. H., Jr. 1972. Population biology of alewives, Alosa pseudoharengus, in Lake Michigan, 1949-1970. J. Fish. Res. Board Can. 29:477-500.

Brown, H. W. 1974. Handbook of the effects of temperature on some North American fishes. Amer. Electric Power Serv. Co. Environ. Eng. Div., Canton, Ohio. 431 pp.

Brynildson, O. M., V. A. Hacker and T. A. Klick. 1973. Brown trout life history, ecology and management. Pub. 234. Wisc. Dept. Nat. Res., Madison, Wisc. 15 pp.

Carlander, K. D. 1969. Handbook of freshwater fishery biology. Vol. I. Iowa State Univ. Press, Ames, Iowa. 431 pp.

Christie, W. J. 1974. Changes in the fish species composition of the Great Lakes. J. Fish. Res. Board Can. 31:827-854.

Clady, M. D. 1976. Influence of temperature and wind on the survival of early stages of yellow perch (Perca flavescens). J. Fish. Res. Board Can. 33:1887-1893.

Cole, R. A. 1978. Larval fish distributions in southwestern Lake Erie near the Monroe Power Plant. EPA-600/3-78-069. Env. Research Lab., Duluth, Minn., U. S. E. P. A. 65 pp.

Conover, N. J. 1971. Practical non-parametric statistics. John Wiley and Sons Inc. New York. 462 pp.

Cooper, G. P. and J. L. Fuller. 1945. A biological survey of Moosehead Lake and Haymock Lake. Maine Dept. Inland Fish. Game. Fish Surv. Rept. No. 6:160 pp.

Cooper, J. E. 1978. Identification of eggs, larvae and juveniles of the rainbow smelt, Osmerus mordax, with comparison to larval alewife, Alosa pseudoharengus, and gizzard shad, Dorosoma cepedianum. Trans. Amer. Fish. Soc. 107:56-62.

Crowder, L. B. 1980. Alewife, rainbow smelt and native fishes in Lake Michigan: competition or predation? Env. Biol. Fish. 5:225-233.

Daly, R. I. and L. W. Wiegert. 1958. The smelt are running! Wisc. Cons. Bull. 23:2 pp.

______, J. Moore and P. Schultz. 1975. Status of fish stocks, Lake Michigan. pp. 67-96. In: Minutes, Lake Michigan Committee annual meeting, Milwaukee, Wisc. (Unpubl. rep.) Great Lakes Fish. Comm., Ann Arbor, Mich.

Deason, H. J. 1939. The distribution of cottid fishes in Lake Michigan. Pap. Mich. Acad. Sci. Arts Lett. 24:105-115.

Dorr, J. A. III and T. J. Miller. 1975. Underwater operations in southeastern Lake Michigan near the Donald C. Cook Nuclear Plant during 1974. Spec. Rep. No. 44, Great Lakes Res. Div., Univ. of Mich. 32 pp.

_____, D. J. Jude, F. J. Tesar and N. J. Thurber. 1976. Identification of larval fishes taken from the inshore waters of southeastern Lake Michigan near the Donald C. Cook Nuclear Plant, 1973-1975. pp. 61-82. In J. Boreman (ed.) Great Lakes fish egg and larvae identification. Nat. Power Plant Team. Off. Biol. Serv. U. S. Fish Wildl. Serv., Ann Arbor, Mich. 220 pp.

_____ and D. J. Jude. 1980. SCUBA assessment of abundance, spawning, and behavior of fishes in southeastern Lake Michigan near the Donald C. Cook Nuclear Plant, 1975-1978. Mich. Acad. 12:345-364.

_____ and _____. 1981. Organization and status of a cooperative Great Lakes regional fish larvae collection. J. Great Lakes Res. 7:194-200.

_____, D. V. O'Connor, N. R. Foster and D. J. Jude. 1981. Substrate conditions and abundance of lake trout eggs in a traditional spawning area in southeastern Lake Michigan. N. Amer. J. Fish. Mgt. (in press).

Draper, N. and H. Smith. 1966. Applied regression analysis. Wiley Inc. New York. 407 pp.

Dryer, W. R. 1963. Age and growth of the whitefish in Lake Superior. U. S. Fish Wildl. Serv. Fish. Bull. 63:77-95.

_____. 1966. Bathymetric distribution of fish in the Apostle Islands region, Lake Superior. Trans. Amer. Fish. Soc. 95:248-259.

Eddy, S. 1957. How to know the freshwater fishes. Wm. C. Brown Co. Dubuque, Iowa. 253 pp.

Edsall, T. A. 1970. The effect of temperature on the rate of development and survival of alewife eggs and larvae. Trans. Amer. Fish. Soc. 99:376-380.

Emery, A. R. 1970. Fish and crayfish mortalities due to an internal seiche in Georgian Bay, Lake Huron. J. Fish. Res. Board Can. 27:1165-1168.

Eschmeyer, P. H. 1957. The lake trout (Salvelinus namaycush). U. S. Dept. of Interior Fish and Wildl. Serv., Fish. Leaflet 441. Ann Arbor, Mich. 11 pp.

Euers, D. 1960. Smelt fishing in Wisconsin. Wisc. Cons. Bull. April 1960:24-27.

Ferguson, R. G. 1958. The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. J. Fish. Res. Board Can. 15:607-624.

_____. 1965. Bathymetric distribution of American smelt Osmerus mordax in Lake Erie. Great Lakes Res. Div., Univ. Mich. Publ. 13:47-60.

Fish, M. P. 1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie and its tributary waters. Bull. U. S. Bur. Fish. 47:293-398.

Flittner, G. A. 1964. Morphometry and life history of the emerald shiner, Notropis atherinoides Rafinesque. Ph.D. Thesis. Univ. Mich., Ann Arbor, Mich. 213 pp.

Fox, D. J. 1978. A set of computer routines for probability distributions and their inverses. Tech. Rep. No. 5. Stat. Res. Lab., Univ. Mich., Ann Arbor, Mich. 4 pp.

_____ and K. E. Guire. 1973. Documentation for MIDAS (Michigan Interactive Data Analysis System). 2nd ed. Stat. Res. Lab., Univ. Mich., Ann Arbor, Mich. 173 pp.

Fuchs, E. H. 1967. Life history of the emerald shiner, Notropis atherinoides, in Lewis and Clark Lake, South Dakota. Trans. Amer. Fish. Soc. 96:247-256.

Geen, G. H., T. G. Northcote, G. F. Hartman and C. C. Lindsey. 1966. Life histories of two species of catostomid fishes in Sixteenmile Lake, British Columbia, with particular reference to inlet stream spawning. J. Fish. Res. Board Can. 23:1761-1788.

Great Lakes Fishery Laboratory. 1972. Status of fish stocks - lake trout. (Unpubl. rep.) Presented at Great Lakes Fishery Comm., Lake Michigan Committee Meeting, Milwaukee, Wisc., 7 March 1972.

_____. 1978. Annual Report of the Great Lakes Fishery Commission for the year 1975. Great Lakes Fishery Comm., Ann Arbor, Mich. 95 pp.

_____. 1979. Annual Report of the Great Lakes Fishery Commission for the year 1976. Great Lakes Fishery Comm., Ann Arbor, Mich. 127 pp.

_____. 1980. Annual Report of the Great Lakes Fishery Commission for the year 1977. Great Lakes Fishery Comm., Ann Arbor, Mich. 121 pp.

Griswold, B. L. and L. L. Smith, Jr. 1972. Early survival and growth of the ninespine stickleback, Pungitius pungitius. Trans. Amer. Fish. Soc. 101:350-352.

_____ and _____. 1973. The life history and trophic relationship of the ninespine stickleback, Pungitius pungitius, in the Apostle Islands area of Lake Superior. U. S. Fish Wildl. Serv. Fish. Bull. 71:1039-1060.

Heinrich, J. W. 1981. Culture, feeding , and growth of alewives hatched in the laboratory. Prog. Fish-Cult. 43:3-7.

Heufelder, G. R. and P. J. Schneeberger. 1980. Occurrence of the acanthocephalan Leptorhynchoides thecatus in slimy sculpins - a new host record. Trans. Amer. Fish. Soc. 109:142-144.

_____ and L. A. Fuiman. (in press) Family Cyprinidae, minnows and carps. In: N. A. Auer, ed. A descriptive manual for the identification of larval fish of the Great Lakes Region with emphasis on the Lake Michigan Basin.

Hinrichs, M. A. 1979. A description and key of the eggs and larvae of five species of fish in the subfamily Coregoninae. M.S. Thesis. Univ. Wisc., Stevens Point, Wisc. 72 pp.

Hoffman, G. L. 1967. Parasites of North American freshwater fishes. Univ. Calif. Press, Los Angeles, Calif. 486 pp.

Hogue, J. J., Jr., R. Wallus and L. K. Kay. 1976. Preliminary guide to the identification of larval fishes in the Tennessee River. TVA, Div. of Forestry, Fisheries, and Wildlife Development Tech. Note 319. 67 pp.

Houde, E. D. 1969. Sustained swimming ability of larvae of walleye (Stizostedion vitreum) and yellow perch (Perca flavescens). J. Fish. Res. Board Can. 26:1647-1659.

House, R. and L. Wells. 1973. Age, growth, spawning season, and fecundity of the trout-perch (Percopsis omiscomaycus) in southeastern Lake Michigan. J. Fish. Res. Board Can. 30:1221-1225.

Hubbs, C. L. and C. W. Creaser. 1924. On the growth of young suckers and the propagation of trout. Ecology 5:372-378.

_____ and K. F. Lagler. 1958. Fishes of the Great Lakes region. Univ. Mich. Press, Ann Arbor, Mich. 213 pp.

Jacoby, C. 1953. Notes on the life history of the deepwater sculpin, Myoxocephalus quadricornis (L.), in Lake Superior. M.Sc. Thesis. Univ. Mich. School Natur. Res., Ann Arbor, Mich. 21 pp.

Jones, J. W. and H. B. N. Hynes. 1950. The age and growth of Gasterosteus aculeatus, Pygosteus pungitius and Spinachia vulgaris, as shown by their otoliths. J. Anim. Ecol. 19:59-73.

Jude, D. J., F. J. Tesar, J. A. Dorr III, T. J. Miller, P. J. Rago and D. J. Stewart. 1975. Inshore Lake Michigan fish populations near the Donald C. Cook Nuclear Power Plant, 1973. Spec. Rep. No. 52, Great Lakes Res. Div., Univ. Mich., Ann Arbor, Mich. 267 pp.

_____, B. A. Bachen, G. R. Heufelder, H. T. Tin, M. H. Winnell, F. J. Tesar and J. A. Dorr, III. 1978. Adult and juvenile fish, ichthyoplankton and benthos populations in the vicinity of the J. H. Campbell Power Plant, eastern Lake Michigan, 1977. Spec. Rep. No. 65, Great Lakes Res. Div., Univ. Mich., Ann Arbor, Mich. 639 pp.

_____, G. R. Heufelder, H. T. Tin, N. A. Auer, S. A. Klinger, P. J. Schneeberger, T. L. Rutecki, C. P. Madenjian and P. J. Rago. 1979a. Adult, juvenile and larval fish in the vicinity of the J. H. Campbell Power Plant, eastern Lake Michigan, 1978. Spec. Rep. No. 73, Great Lakes Res. Div., Univ. Mich., Ann Arbor, Mich. 574 pp.

_____, F. J. Tesar, J. C. Tomlinson, T. J. Miller, N. J. Thurber, G. G. Godun and J. A. Dorr III. 1979b. Inshore Lake Michigan fish populations near the D. C. Cook Nuclear Power Plant during preoperational years - 1973, 1974. Spec. Rep. No. 71, Great Lakes Res. Div., Univ. Mich., Ann Arbor, Mich. 529 pp.

_____, G. R. Heufelder, N. A. Auer, H. T. Tin, S. A. Klinger, P. J. Schneeberger, C. P. Madenjian, T. L. Rutecki and G. G. Godun. 1980. Adult, juvenile and larval fish populations in the vicinity of the J. H. Campbell Power Plant, eastern Lake Michigan, 1979. Spec. Rep. No. 79, Great Lakes Res. Div., Univ. Mich., Ann Arbor, Mich. 607 pp.

_____, T. L. Rutecki, C. P. Madenjian, G. E. Noguchi, P. J. Schneeberger, S. A. Klinger, G. G. Godun and M. H. Winnell. 1981a. The physical, chemical and biological nature of Pigeon Lake, a Lake Michigan coastal lake. Spec. Rep. No. 78, Great Lakes Res. Div., Univ. Mich., Ann Arbor, Mich. 109 pp.

_____, S. A. Klinger and M. D. Enk. 1981b. Evidence of natural reproduction of planted lake trout in Lake Michigan. J. Great Lakes Res. 7:57-61.

Kendall, W. C. 1927. The smelts. Bull. U. S. Bur. Fish. 42:217-375.

Kinney, E. C. Jr. 1950. The life history of the trout perch, _Percopsis omiscomaycus_ (Walbaum), in western Lake Erie. M.Sc. Thesis. Ohio State Univ., Columbus, Ohio. 75 pp.

Koehler, F. E. 1978. Life history studies of the longnose sucker, _Catostomus catostomus_, and the white sucker, _Catostomus commersoni_ in nearshore eastern Lake Michigan near Ludington, Michigan. 1978 Annual Report to Consumers Power Co., Ludington Project, Vol. 1, No. 4. Dept. Fish. Wildl., Mich. State Univ., East Lansing, Mich. 56 pp.

Koelz, W. 1929. Coregonid fishes of the Great Lakes. Bull. U. S. Bur. Fish. 43:297-643.

Koster, W. J. 1936. The life-history and ecology of the sculpins (Cottidae) of central New York. Ph.D. Thesis. Cornell Univ., Ithaca, N. Y. 87 pp.

Lawler, G. H. 1954. Observations on the trout-perch _Percopsis omiscomaycus_ (Walbaum), at Heming Lake, Manitoba. J. Fish. Res. Board Can. 11:1-4.

Lawrie, A. H. and J. F. Rahrer. 1973. Lake Superior: a case history of the lake and its fisheries. Tech. Rep. No. 19, Great Lakes Fish. Comm., Ann Arbor, Mich. 69 pp.

Legault, R. O. and C. Delisle. 1968. La fraye d'une population d'eperlans geants, Osmerus eperlanus mordax, au Lac Heney, Comte de Gatineau, Quebec. J. Fish. Res. Board Can. 25:1813-1830.

Lippson, A. J. and R. L. Moran. 1974. Manual for identification of early developmental stages of fishes of the Potomac River Estuary. Environ. Tech. Cent., Martin Marietta Corp., Baltimore, Md. 282 pp.

Liston, C. R. and P. I. Tack. 1973. A study of the effects of installing and operating a large pumped storage project on the shores of Lake Michigan. Final Report (Phase I) to Consumers Power Co. Dept. of Fisheries and Wildl., Mich. State Univ., East Lansing, Mich. 113 pp.

_____ and _____. 1976. A study of water currents and temperatures in Lake Michigan adjacent to the James H. Campbell Power Plant at Port Sheldon, Michigan. Dept. of Fisheries and Wildl., Mich. State Univ., East Lansing, Mich. 66 pp.

_____, D. Brazo, J. Bohr, R. Ligman, R. O'Neal and G. Peterson. 1980. Results of 1978 aquatic research at the Ludington Pumped Storage Power Plant on Lake Michigan including entrainment of fish and invertebrates, turbine mortalities, reservoir residence periods of salmonid fishes, netting and hydroacoustic surveys and water currents. 1978 Annual Report to Consumers Power Co., Ludington Project, Vol. I. Dept. of Fish. and Wildl., Mich. State Univ., Ludington Res. Lab. 221 pp.

_____, _____, R. O'Neal, J. Bohr, G. Peterson and R. Ligman. 1981. Assessment of larval, juvenile, and adult fish entrainment losses at the Ludington Pumped Storage Power Plant on Lake Michigan. 1980 Annual Report to Consumers Power Co., Ludington Project, Vol. I. Dept. of Fish. and Wildl., Mich. State Univ. East Lansing, Mich. 275 pp.

MacCallum, W. R. and M. A. Regier. 1970. Distribution of smelt, Osmerus mordax and the smelt fishery in Lake Erie in the early 1960s. J. Fish. Res. Board Can. 27:1823-1846.

MacCrimmon, H. R. and B. L. Gots. 1972. Rainbow trout in the Great Lakes. Ontario Ministry of Natural Resources, Sport Fish. Branch. 66 pp.

Machniak, K. 1975. The effects of hydroelectric development on the biology of northern fishes (reproduction and population dynamics). I. Lake whitefish Coregonus clupeaformis (Mitchill), a literature review and bibliography. Fish. and Marine Serv. Tech. Rep. No. 527, Environment Canada. 67 pp.

Magnuson, J. L. and L. L. Smith, Jr. 1963. Some phases of the life history of the trout-perch. Ecology 44:83-85.

McCauley, R. W. and J. S. Tait. 1970. Preferred temperature of yearling lake trout, Salvelinus namaycush. J. Fish. Res. Board Can. 27:1729-1733.

McComish, T. S. and W. B. Miller. 1975. Notes on the biology of the lake trout and other selected Salmonidae in Indiana waters of Lake Michigan. Proc. Ind. Acad. Sci. 85:161-169.

McCrimmon, H. R. 1968. Carp in Canada. Fish. Res. Board Can. Bull. 165. 93 pp.

McKenzie, J. A. and M. H. A. Keenleyside. 1970. Reproductive behavior of ninespine sticklebacks (Pungitius pungitius (L.)) in South Bay, Manitoulin Island, Ontario. Can. J. Zool. 48:55-61.

McKenzie, R. A. 1964. Smelt life history and fishery in the Miramichi River, New Brunswick. Fish. Res. Board Can. Bull. 144. 77 pp.

Mortimer, C. H. 1975. Environmental status of the Lake Michigan Region. Vol. 2. Physical limnology of Lake Michigan. Part 1: Physical characteristics of Lake Michigan and its responses to applied forces. Environ. Cont. Techn. Earth Sci. Argonne Nat. Lab., Argonne, Ill. 121 pp.

Mozley, S. C. 1975. Preoperational investigations of zoobenthos in southeastern Lake Michigan near the Cook Nuclear Plant. Spec. Rep. No. 56, Great Lakes Res. Div., Univ. Mich., Ann Arbor, Mich. 132 pp.

Mraz, D. 1964. Age and growth of the round whitefish in Lake Michigan. Trans. Amer. Fish. Soc. 93:46-52.

Muth, K. M. 1973. Population dynamics and life history of burbot, Lota lota (Linnaeus), in Lake of the Woods, Minnesota. Ph.D. Thesis. Univ. Minn., St. Paul, Minn. 164 pp.

Nelson, D. D. and R. A. Cole. 1975. The distribution and abundance of larval fishes along the western shore of Lake Erie at Monroe, Michigan. Tech. Rep. No. 32.4. Inst. Water Research, Mich. State Univ., East Lansing, Mich. 66 pp.

Nelson, J. S. 1968. Deepwater ninespine sticklebacks, Pungitius pungitius, in the Mississippi drainage, Crooked Lake, Indiana. Copeia 1968:326-334.

Normandeau, D. A. 1969. Life history and ecology of the round whitefish, Prosopium cylindraceum (Pallas), of Newfound Lake, Bristol, New Hampshire. Trans. Amer. Fish. Soc. 98:7-13.

Nursall, J. R. and M. W. Pinsent. 1969. Aggregations of spottail shiners and yellow perch. J. Fish. Res. Board Can. 26:1672-1676.

Patriarche, H. M. 1980. Movement and harvest of coho salmon in Lake Michigan 1978-1979. Mich. Dept. Nat. Res. Fish. Div., Fish. Res. Rep. 1889. 52 pp.

Pitt, T. K., E. T. Garside and R. L. Hepburn. 1956. Temperature selection of the carp (Cyprinus carpio Linn.). Can. J. Zool. 34:555-557.

Price, J. W. 1963. A study of the food habits of some Lake Erie fish. Bull. Ohio Biol. Surv. 2:1-89.

Randall, W. H. and R. J. Landon. 1981. Licensing the wastewater discharges and circulating system for James H. Campbell 3. Presented at Amer. Power Conf., Chicago, Ill. Gilbert/Commonwealth Engineers/Consultants, Jackson, Mich. 16 pp.

Rawson, D. S. 1951. Studies of the fish of Great Slave Lake. J. Fish. Res. Board Can. 8:207-240.

Reigle, N. J. Jr. 1969. Bottom trawl explorations in southern Lake Michigan, 1962-1965. Circ. 301. U. S. Fish. Wildl. Serv. Bur. Comm. Fish., Washington, D. C. 35 pp.

Reutter, J. M. and C. E. Herdendorf. 1974. Laboratory estimates of the seasonal final temperature preferenda of some Lake Erie fish. Proc. 17th Conf. Great Lakes Res., Internat. Assoc. Great Lakes Res. pp. 59-67.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can. Bull. 191. 382 pp.

Robins, C. R., R. M. Bailey, C. E. Bond, J. R. Brooker, E. A. Lachner, R. N. Lea and W. B. Scott. 1980. A list of common and scientific names of fishes from the United States and Canada. 4th ed. Spec. Pub. No. 12, Amer. Fish. Soc. 174 pp.

Roelofs, E. W. 1958. Age and growth of whitefish, Coregonus clupeaformis (Mitchill), in Big Bay de Noc and northern Lake Michigan. Trans. Amer. Fish. Soc. 87:190-199.

Romberg, G. P., S. A. Spigarelli, W. Prepejchal and M. M. Thommes. 1974. Fish behavior at a thermal discharge into Lake Michigan. pp. 296-312 In: J. W. Gibbons and R. R. Sharitz (eds.) Thermal Ecology. Argonne Environ. Lab. Symposium Ser. 670 pp.

Rottiers, D. V. 1965. Some aspects of the life history of Cottus cognatus in Lake Michigan. M.S. Thesis. Univ. Mich., Ann Arbor, Mich. 49 pp.

Rupp, R. S. 1959. Variation in the life history of the American smelt in inland waters of Maine. Trans. Amer. Fish. Soc. 88:241-252.

_____. 1965. Shore-spawning and survival of eggs of the American smelt. Trans. Amer. Fish Soc. 94:160-168.

Rybicki, R. W. and M. Keller. 1978. The lake trout resource in Michigan waters of Lake Michigan, 1970-1976. Mich. Dept. Nat. Res., Fish. Div., Fish. Res. Rep. 1863. 71 pp.

Schneeberger, P. J. and D. J. Jude. 1981. Use of fish larva morphometry to predict exclusion capabilities of small-mesh screens at cooling-water intakes. Trans. Amer. Fish. Soc. 110:246-252.

Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Board Can. Bull. 184. 966 pp.

Sette, O. E. 1943. Biology of the Atlantic mackerel (Scomber scombrus) of North America. Part I: early life history, including growth, drift, and mortality of egg and larval populations. U. S. Fish. Wildl. Serv. Fish. Bull. 50:145-237.

Smiley, C. W. 1881. A statistical review of the production and distribution to public waters of young fish by the United States Commission from its organization in 1871 to the close of 1880. Rept. of the U. S. Comm. of Fish and Fisheries, part 9:915. In: MacCrimmon and Gots (1972).

Smith, S. H. 1968. Species succession and fishery exploitation in the Great Lakes. J. Fish. Res. Board Can. 25:667-693.

_____. 1970. Species interactions of the alewife in the Great Lakes. Trans. Amer. Fish. Soc. 99:754-765.

Spigarelli, S. A. 1975. Behavioral responses of Lake Michigan fishes to a nuclear power plant discharge. pp. 479-498. In: Environmental effects of cooling systems at nuclear power stations. Int. Atomic Energy Agency, Vienna. 829 pp.

Statistical Research Laboratory. 1975. Analysis of variance - BMD8V - general description. Unpub. ms. Stat. Res. Lab., Univ. Mich., Ann Arbor, Mich. 3 pp.

Swee, U. B. and H. R. McCrimmon. 1966. Reproductive biology of the carp, Cyprinus carpio L., in Lake St. Lawrence, Ontario. Trans. Amer. Fish. Soc. 95:372-380.

Threinen, C. W. 1958. Life history, ecology, and management of the alewife. Wisc. Conserv. Dept. Publ. 223:1-7.

Tody, W. H. 1973. Michigan's Great Lakes trout and salmon fishery 1969-1972. Mich. Dept. Nat. Res. Fish Mgt. Rep. 5. 105 pp.

_____ and H. A. Tanner. 1966. Coho salmon for the Great Lakes. Mich. Dept. Conserv. Fish Mgt. Rep. 1. 38 pp.

Toth, R. J. 1959. Studies on the life history of the yellow perch, Perca flavescens (Mitchill), in Big Bay de Noc, Lake Michigan. M.S. Thesis. Mich. State Univ., E. Lansing, Mich. 86 pp.

Trautman, M. B. 1957. The fishes of Ohio with illustrated keys. Ohio State Univ. Press, Columbus, Ohio. 683 pp.

U. S. Army Corps of Engineers. 1971. National Oceanic and Atmospheric Administration. National Ocean Survey. Washington, D. C.

Van Oosten, J. 1939. The age, growth, sexual maturity and sex ratio of the common whitefish, Coregonus clupeaformis (Mitchill), of Lake Huron. Pap. Mich. Acad. Sci. Arts Lett. 24:195-221.

_____. 1940. The smelt, Osmerus mordax (Mitchill). Great Lakes Fish. Invest. U. S. Bur. Fish. 13 pp. (Unpublished report).

_____ and H. J. Deason. 1938. The food of the lake trout (Cristivomer namaycush) and of the lawyer (Lota maculosa) of Lake Michigan. Trans. Amer. Fish. Soc. 67:157-177.

_____, R. Hile and F. W. Jobes. 1946. The whitefish fishery of Lakes Huron and Michigan with special reference to the deep trap net fishery. U. S. Fish. Wildl. Serv. Fish. Bull. 50:297-394.

_____ and R. Hile. 1949. Age and growth of the lake whitefish, Coregonus clupeaformis (Mitchill), in Lake Erie. Trans. Amer. Fish Soc. 77:178-249.

Van Vliet, W. H. 1964. An ecological study of Cottus cognatus Richardson in northern Saskatchewan. M.A. Thesis. Dept. Biol., Univ. Saskatchewan, Saskatoon, Sask. 155 pp.

WAPORA. 1979. Aquatic survey of Lake Michigan near the Palisades Nuclear Plant. Part 4 of 6: Ichthyoplankton. WAPORA, Inc. Lansing, Mich. 101 pp.

Water Resources Commission. 1968. The water resources of the lower Lake Michigan drainage basin. Mich. Water Res. Comm. Lansing, Mich. 172 pp.

Waybrant, R. C. and J. M. Shauver. 1979. Survey of larval fish in the Michigan waters of Lake Erie, 1975 and 1976. EPA-600/3-79-095. Env. Res. Lab., Duluth, U. S. Env. Prot. Agency. 86 pp.

Wells, L. 1968. Seasonal depth distribution of fish in southeastern Lake Michigan. U. S. Fish Wildl. Serv. Fish. Bull. 67:1-15.

_____. 1973. Distribution of fish fry in nearshore waters of southeastern and east-central Lake Michigan, May-August 1972. Admin. Rep. Great Lakes Fish. Lab., Ann Arbor, Mich. 24 pp.

_____. 1974. Distribution of fish fry in nearshore waters of southern and central Lake Michigan, May-August 1973. Admin. Rep. Great Lakes Fish. Lab., Ann Arbor, Mich. 22 pp.

_____. 1977. Changes in yellow perch (Perca flavescens) populations of Lake Michigan, 1954-75. J. Fish. Res. Board Can. 34:1821-1829.

_____ and A. L. McLain. 1972. Lake Michigan: effects of exploitation, introductions and eutrophication on the salmonid community. J. Fish. Res. Board Can. 29:889-898.

_____ and _____. 1973. Lake Michigan - man's effects on native fish stocks and other biota. Tech. Rep. 20. Great Lakes Fish. Comm. Ann Arbor, Mich. 55 pp.

_____ and R. House. 1974. Life history of the spottail shiner (Notropis hudsonius) in southeastern Lake Michigan, the Kalamazoo River and western Lake Erie. Research Rep. No. 78. Bur. Sport Fish. and Wildl., Washington, D. C. 10 pp.

Westin, L. 1969. The mode of fertilization, parental behavior and time of egg development in fourhorn sculpin, Myoxocephalus quadricornis (L.). Rep. Inst. Freshw. Res. Drottningholm 49:175-182.

Westman, J. R. 1938. Studies on the reproduction and growth of the bluntnose minnow, Hyborhynchus notatus (Rafinesque). Copeia 1938:57-60.

Winn, H. E. 1958. Comparative reproductive behavior and ecology of fourteen species of darters (Pisces - Percidae). Ecol. Monogr. 28:155-191.

Winnell, M. H. and D. J. Jude. 1979. Spatial and temporal distribution of benthic macroinvertebrates and sediments collected in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1978. Spec. Rep. No. 75, Great Lakes Res. Div., Univ. Mich., Ann Arbor, Mich. 199 pp.

_____ and _____. 1980. Spatial and temporal distribution of benthic macroinvertebrates and sediments collected in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1979. Spec. Rep. No. 77, Great Lakes Res. Div., Univ. Mich., Ann Arbor, Mich. 138 pp.

Wong, B. 1972. Growth, feeding and distribution of yellow perch fry, Perca fluviatilis flavescens (Mitchill), during their first summer in West Blue Lake. M.S. Thesis. Univ. Manitoba, Winnipeg, Man. 92 pp.

Yager, R. 1976. Food habits of the spottail shiner in Indiana waters of Lake Michigan in 1973. M.S. Thesis. Ball State Univ., Muncie, Ind. 103 pp.

Yocum, W. L. and F. J. Tesar. 1980. Sled for sampling benthic fish larvae. Prog. Fish-Cult. 42:118-119.

Zeitoun, I. H., J. A. Gulvas and D. B. Roarabaugh. 1981. Effectiveness of fine mesh cylindrical wedge-wire screens in reducing entrainment of Lake Michigan ichthyoplankton. Can. J. Fish. Aquat. Sci. 38:120-125.

INDEX TO FISH SPECIES

APPENDIXES
TO

ADULT, JUVENILE AND LARVAL FISH POPULATIONS IN THE VICINITY OF THE J. H. CAMPBELL POWER PLANT, EASTERN LAKE MICHIGAN, 1977-1980.

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November, 1981

APPENDIXES

Appendix 1. Alphabetical listing of code letters and common names of all fish species and species groups captured in Lake Michigan near the J. H. Campbell Plant, 1977 to 1980.

Code	Common name	Code	Common name
AL	Alewife	MA	Silver Redhorse
BC	Black Crappie	MM	Central Mudminnow
BG	Bluegill	MS	Mottled Sculpin
BM	Bluntnose Minnow	NP	Northern Pike
BL	Bloater	NS	Ninespine Stickleback
BR	Burbot	PM	Unidentified *Pomoxis* spp.
BT	Brown Trout	PP	Fathead Minnow
CC	Channel Catfish	PS	Pumpkinseed
CH	Chinook Salmon	QL	Quillback
CM	Coho Salmon	RT	Rainbow Trout
CP	Common Carp	RW	Round Whitefish
ES	Emerald Shiner	SB	Smallmouth Bass
FD	Freshwater Drum	SM	Rainbow Smelt
FS	Deepwater Sculpin	SP	Spottail Shiner
GF	Goldfish	SR	Shorthead Redhorse
GL	Golden Shiner	SS	Slimy Sculpin
GN	Green Sunfish	SV	Brook Silverside
GR	Golden Redhorse	TP	Trout-perch
GS	Gizzard Shad	UC	Unidentified Cottidae
JD	Johnny Darter	WL	Walleye
LD	Longnose Dace	WS	White Sucker
LG	Lake Sturgeon	XC	Unidentified Coregoninae
LH	Lake Herring	XG	Unidentified Stickleback
LP	Logperch	XL	Unidentified *Lepomis* spp.
LS	Longnose Sucker	XM	Unidentified Cyprinidae
LT	Lake Trout	XP	Damaged Larvae
LW	Lake Whitefish	XS	Unidentified Catostomidae
XX	Unidentified Pisces	YB	Yellow Bullhead
YP	Yellow Perch		

Appendix 2. Meteorological and limnological parameters measured during gillnetting, April to November 1980 near the J. H. Campbell Plant, eastern Lake Michigan. * = surface gill net.

STARTING DATE	TIME		STATION	TEMPERATURE C		WIND		WAVES		WEATHER	SECCHI DISC (M)
	START	FINISH		SURFACE	FISH DEPTH	DIR. FROM	SPEED MPH	DIR. FROM	HT. (M)		
4-21-80	2045	0550	A	9.0	9.0	S	5-10	SW	0-0.3	CLEAR	-
4-29-80	0945	1720	A	8.0	7.2	ENE	0-5	NW	0-0.3	OVERCAST	1.5
4-21-80	2050	0600	B	7.0	7.0	ESE	5-10	SW	0-0.3	CLEAR	-
4-29-80	0955	1725	B	7.2	6.5	ENE	0-5	NW	0-0.3	OVERCAST	1.5
4-21-80	2057	0620	C	6.0	5.8	ESE	5-10	SW	0-0.3	CLEAR	-
4-29-80	1005	1735	C	6.8	5.5	E	0-5	NW	0-0.3	OVERCAST	2.5
4-21-80	2104	0615	C*	6.0	6.0	ESE	5-10	SW	0-0.3	CLEAR	-
4-29-80	1010	1735	C*	6.8	6.8	E	0-5	NW	0-0.3	OVERCAST	2.5
4-21-80	2108	0630	D	5.0	5.0	S	0-5	S	0-0.3	CLEAR	-
4-29-80	1015	1745	D	6.0	4.8	E	0-5	NW	0-0.3	OVERCAST	2.5
4-21-80	2114	0637	E	4.5	4.5	S	0-5	S	0-0.3	CLEAR	-
4-29-80	1020	1755	E	5.0	3.8	E	0-5	NW	0-0.3	OVERCAST	3.0
4-21-80	1955	0542	L	5.5	5.5	ESE	5-10	CALM	CALM	CLEAR	-
4-29-80	1050	1830	L	6.2	5.2	E	0-5	NW	0-0.3	OVERCAST	2.0
4-29-80	1045	1835	L*	6.2	6.2	E	0-5	NW	0-0.3	OVERCAST	2.0
4-21-80	1950	0538	L*	5.5	5.5	ESE	5-10	CALM	CALM	CLEAR	-
4-21-80	2015	0612	N	4.5	4.5	ESE	5-10	CALM	CALM	CLEAR	-
4-29-80	1115	1855	N	6.5	5.5	E	0-5	NW	0-0.3	OVERCAST	2.0
4-21-80	2009	0604	U	5.5	5.5	ESE	5-10	CALM	CALM	CLEAR	-
4-29-80	1105	1850	U	6.8	5.5	E	0-5	NW	0-0.3	OVERCAST	2.0
4-29-80	1110	1845	U*	6.8	6.8	E	0-5	NW	0-0.3	OVERCAST	2.0
4-21-80	2000	0553	U*	5.5	5.5	ESE	5-10	CALM	CALM	CLEAR	-
5-19-80	0630	2012	A	8.3	8.3	ESE	0-5	CALM	CALM	FOG	BOTTOM
5-19-80	2012	0615	A	10.0	9.5	NW	0-5	NW	0-0.3	CLEAR	-
5-19-80	0638	2003	B	8.3	8.0	ESE	0-5	CALM	CALM	PT CLOUDY	2.5
5-19-80	2003	0610	B	9.3	8.5	NW	0-5	NW	0-0.3	CLEAR	-
5-19-80	0652	1935	C	8.0	7.5	ESE	0-5	CALM	CALM	PT CLOUDY	2.5
5-19-80	1935	0555	C	8.0	6.5	NW	0-5	NW	0-0.3	CLEAR	-
5-19-80	0645	1955	C*	8.0	8.0	ESE	0-5	CALM	CALM	PT CLOUDY	2.5
5-19-80	1955	0603	C*	8.0	8.0	NW	0-5	NW	0-0.3	CLEAR	-
5-19-80	0700	1920	D	7.8	6.8	SSE	0-5	CALM	CALM	FOG	3.0
5-19-80	1920	0545	D	8.8	6.4	NW	0-5	NW	0-0.3	CLEAR	-
5-19-80	0705	1905	E	7.8	6.1	SSE	0-5	CALM	CALM	FOG	3.0
5-19-80	1905	0535	E	8.9	5.3	NW	0-5	NW	0-0.3	CLEAR	-
5-19-80	0745	1900	L	8.3	7.5	ESE	0-5	CALM	CALM	PT CLOUDY	3.0
5-19-80	1900	0535	L	9.2	7.9	NW	0-5	NW	0-0.3	CLEAR	-
5-19-80	0739	1900	L*	8.3	8.3	ESE	0-5	CALM	CALM	PT CLOUDY	3.0
5-19-80	1900	0530	L*	9.2	9.2	NW	0-5	NW	0-0.3	CLEAR	-
5-19-80	0805	1930	N	7.8	7.2	ESE	0-5	CALM	CALM	PT CLOUDY	3.0
5-19-80	1930	0605	N	9.6	6.9	NW	0-5	NW	0-0.3	CLEAR	-
5-19-80	0750	1915	U	8.3	7.5	ESE	0-5	CALM	CALM	PT CLOUDY	3.0
5-19-80	1915	0555	U	9.2	7.9	NW	0-5	NW	0-0.3	CLEAR	-
5-19-80	0755	1915	U*	8.3	8.3	ESE	0-5	CALM	CALM	PT CLOUDY	3.0
5-19-80	1915	0545	U*	9.2	9.2	NW	0-5	NW	0-0.3	CLEAR	-
6-16-80	0635	2020	A	11.9	11.6	CALM	0-5	WNW	0.6-1.0	PT CLOUDY	1.0

Appendix 2. Continued.

STARTING DATE	TIME START	TIME FINISH	STATION	TEMPERATURE C SURFACE	TEMPERATURE C FISH DEPTH	WIND DIR. FROM	WIND SPEED MPH	WAVES DIR. FROM	WAVES HT. (M)	WEATHER	SECCHI DISC (M)
6-16-80	2030	0540	A	12.0	11.0	NW	0-5	NW	0.3-0.6	CLEAR	-
6-16-80	0645	2015	B	11.1	10.5	NE	0-5	WNW	0.6-1.0	PT CLOUDY	1.5
6-16-80	2025	0545	B	11.1	10.5	NW	0-5	NW	0.3-0.6	CLEAR	-
6-16-80	0659	2005	C	10.3	9.3	NE	0-5	WNW	0.6-1.0	PT CLOUDY	2.0
6-16-80	2005	0605	C	10.3	9.3	NW	0-5	NW	0.3-0.6	CLEAR	-
6-16-80	0704	1955	C*	10.3	9.3	NE	0-5	WNW	0.6-1.0	PT CLOUDY	2.0
6-16-80	1955	0555	C*	10.3	9.3	NW	0-5	NW	0.3-0.6	CLEAR	-
6-16-80	0712	1945	D	10.2	8.2	NE	0-5	WNW	0.6-1.0	PT CLOUDY	2.0
6-16-80	1945	0555	D	10.2	8.2	VAR	0-5	VAR	0.6-1.0	CLEAR	-
6-16-80	0720	1930	E	10.0	7.8	NE	0-5	WNW	0.6-1.0	PT CLOUDY	0.5
6-16-80	1930	0600	E	9.2	7.3	VAR	0-5	VAR	0.6-1.0	CLEAR	-
6-16-80	0805	1930	L	8.9	7.3	NE	0-5	WNW	0.6-1.0	PT CLOUDY	1.75
6-16-80	1930	0545	L	10.4	10.4	NW	0-5	NW	0.3-0.6	CLEAR	-
6-16-80	0750	1930	L*	8.9	7.3	NE	5-10	WNW	0.6-1.0	PT CLOUDY	1.75
6-16-80	1930	0540	L*	10.4	10.4	NW	0-5	NW	0.3-0.6	CLEAR	-
6-16-80	0741	2022	N	8.0	7.3	NE	0-5	WNW	0.6-1.0	PT CLOUDY	2-0
6-16-80	2022	0555	N	10.0	7.0	NW	0-5	NW	0.3-0.6	CLEAR	-
6-16-80	0757	1951	U	8.9	7.3	NE	0-5	WNW	0.6-1.0	PT CLOUDY	1.75
6-16-80	1951	0540	U	10.4	10.4	NW	0-5	NW	0.3-0.6	CLEAR	-
6-16-80	0802	1930	U*	8.9	7.3	NE	0-5	WNW	0.6-1.0	PT CLOUDY	1.75
6-16-80	1930	0525	U*	10.4	10.4	NW	0-5	NW	0.3-0.6	CLEAR	-
7-14-80	0925	1910	A	20.0	20.0	SW	15-20	S	0.6-1.0	CLEAR	BOTTOM
7-15-80	2106	0720	A	23.0	23.0	VAR	0-5	SW	0.0-0.3	CLEAR	-
7-14-80	0932	1915	B	19.0	19.0	SW	15-20	SW	0.6-2.0	CLEAR	2.0
7-15-80	2100	0735	B	22.8	22.8	VAR	0-5	SW	0.0-0.3	CLEAR	-
7-14-80	0850	1920	C	20.5	20.0	SW	15-20	SW	0.6-1.0	CLEAR	4.5
7-15-80	2056	0740	C	22.5	21.2	VAR	0-5	SW	0.0-0.3	CLEAR	-
7-15-80	0950	1925	C*	20.5	20.0	SW	15-20	S	0.6-1.0	CLEAR	4.5
7-15-80	2052	0800	C*	22.5	22.5	VAR	0-5	SW	0-0.3	CLEAR	---
7-14-80	0955	1935	D	20.5	20.0	SW	15-20	SW	0.3-0.6	OVERCAST	4.5
7-15-80	2044	0805	D	22.0	20.8	VAR	0-5	SW	0.3-0.6	CLEAR	---
7-14-80	1000	1945	E	20.0	18.5	SW	15-20	SW	0.3-0.6	OVERCAST	5.0
7-15-80	2038	0810	E	21.3	19.8	VAR	0-5	SW	0.3-0.6	CLEAR	---
7-14-80	1000	1910	L	20.5	20.0	SW	15-20	SW	0.6-1.0	CLEAR	4.0
7-15-80	2033	0715	L	21.8	20.5	N	0-5	SW	0-0.3	CLEAR	---
7-14-80	1005	1915	L*	20.0	18.5	SW	15-20	SW	0.6-1.0	CLEAR	4.0
7-15-80	2035	0721	L*	21.8	21.8	N	0-5	SW	0-0.3	CLEAR	---
7-14-80	1020	1920	N	20.5	17.5	SW	15-20	SW	0.6-1.0	CLEAR	6.0
7-15-80	2050	0740	N	21.7	20.3	N	0-5	SW	0-0.3	CLEAR	---
7-14-80	1010	1855	U	20.5	20.0	SW	15-20	SW	0.6-1.0	CLEAR	4.0
7-15-80	2040	0730	U	21.8	20.5	N	0-5	SW	0-0.3	CLEAR	---
7-14-80	1015	1900	U*	20.5	20.5	SW	15-20	SW	0.6-1.0	CLEAR	4.0
7-15-80	2045	0735	U*	21.8	21.8	N	0-5	SW	0-0.3	CLEAR	---
8-18-80	1930	0627	A	19.5	17.5	SW	5-10	SW	0-0.3	CLEAR	---
8-19-80	1000	1917	A	19.0	17.0	SW	10-15	SW	0.6-1.0	OVERCAST	BOTTOM

Appendix 2. Continued.

STARTING DATE	TIME START	TIME FINISH	STATION	TEMPERATURE C SURFACE	TEMPERATURE C FISH DEPTH	WIND DIR. FROM	WIND SPEED MPH	WAVES DIR. FROM	WAVES HT. (M)	WEATHER	SECCHI DISC (M)
8-18-80	1933	0618	B	19.0	16.5	SW	5-10	SW	0-0.3	CLEAR	---
8-19-80	0955	1911	B	18.5	14.5	SW	10-15	SW	0.6-1.0	OVERCAST	---
8-18-80	1940	0613	C	19.0	14.0	SW	5-10	SW	0-0.3	CLEAR	---
8-19-80	0945	1903	C	19.5	16.0	SW	10-15	SW	0.6-1.0	OVERCAST	4.0
8-18-80	1945	0607	C*	19.0	19.0	SW	5-10	SW	0-0.3	CLEAR	---
8-19-80	0950	1858	C*	19.5	19.5	SW	10-15	SW	0.6-1.0	OVERCAST	4.0
8-18-80	1950	0555	D	19.0	14.0	SW	5-10	SW	0-0.3	CLEAR	---
8-19-80	0940	1849	D	20.0	11.3	SW	10-15	SW	0.6-1.0	OVERCAST	5.0
8-18-80	1958	0552	E	19.0	10.0	W	5-10	SW	0-0.3	CLEAR	---
8-19-80	0935	1838	E	20.0	8.5	SW	10-15	SW	0.6-1.0	OVERCAST	5.5
8-18-80	1925	0600	L	20.0	16.0	SW	0-5	WS	0-0.3	CLEAR	---
8-19-80	0950	1835	L	19.2	15.4	SW	10-15	SW	0.6-1.0	OVERCAST	3.5
8-19-80	0955	1845	L*	19.2	19.2	SW	10-15	SW	0.6-1.0	OVERCAST	---
8-18-80	1930	0610	L*	20.0	16.0	SW	0-5	SW	0-0.3	CLEAR	---
8-18-80	1920	0545	N	20.3	15.0	SW	0-5	SW	0-0.3	CLEAR	---
8-19-80	1000	1910	N	19.4	11.9	SW	10-15	SW	0.6-1.0	OVERCAST	5.5
8-18-80	1935	0615	U	20.0	16.0	SW	0-5	SW	0-0.3	CLEAR	---
8-19-80	1000	1850	U	19.2	15.4	SW	10-15	SW	0.6-1.0	OVERCAST	3.5
8-19-80	1005	1900	U*	19.2	19.2	SW	10-15	SW	0.6-1.0	OVERCAST	3.5
8-18-80	1940	0625	U*	20.0	20.0	SW	0-5	SW	0-0.3	CLEAR	---
9-17-80	0701	1430	A	16.0	15.8	NE	5-10	NW	0.3-0.6	OVERCAST	2.0
9-17-80	1915	0710	A	14.8	14.6	NW	5-10	NW	0-0.3	PT CLOUDY	---
9-17-80	0705	1430	B	16.8	16.3	NE	5-10	NW	0.3-0.6	OVERCAST-	2.0
9-17-80	1910	0700	B	15.0	14.8	NW	5-10	NW	0-0.3	PT CLOUDY	---
9-17-80	0711	1430	C	16.8	13.0	NE	5-10	NW	0.3-0.6	OVERCAST	1.5
9-17-80	1910	0650	C	15.5	15.2	NW	5-10	NW	0-0.3	PT CLOUDY	---
9-17-80	0714	1414	C*	16.8	16.8	NE	5-10	NW	0.3-0.6	OVERCAST	1.5
9-17-80	1900	0640	C*	15.5	15.5	NW	5-10	NW	0-0.3	PT CLOUDY	---
9-17-80	0720	1415	D	16.8	11.0	NE	5-10	NW	0.3-0.6	OVERCAST	1.75
9-17-80	1850	0630	D	17.4	11.0	NW	5-10	NW	0-0.3	PT CLOUDY	---
9-17-80	0725	1405	E	17.0	10.7	NE	5-10	NW	0.3-0.6	OVERCAST	2.0
9-17-80	1845	0620	F	17.4	7.3	N	5-10	NW	0.3-0.6	PT CLOUDY	---
9-17-80	0715	1400	L	17.0	15.8	NE	10-15	NW	0.3-0.6	OVERCAST	2.0
9-17-80	1855	0702	L	17.2	16.2	W	0-5	NW	0.3-0.6	PT CLOUDY	2.25
9-17-80	1900	0650	L*	17.2	17.2	W	0-5	NW	0.3-0.6	PT CLOUDY	2.25
9-17-80	0650	1350	N	17.2	12.2	NE	10-15	NW	0.3-0.6	OVERCAST	2.5
9-17-80	1852	0620	N	17.2	14.8	W	0-5	NW	0.3-0.6	PT CLOUDY	2.5
9-17-80	0700	1412	U	17.0	15.8	NE	10-15	NW	0.3-0.6	OVERCAST	2.0
9-17-80	1905	0645	U	17.0	16.0	W	0-5	NW	0.3-0.6	PT CLOUDY	---
9-17-80	0720	1420	U*	17.0	17.0	NE	10-15	NW	0.3-0.6	OVERCAST	2.0
9-17-80	1910	0635	U*	17.0	16.0	NW	0-5	NW	0.3-0.6	PT CLOUDY	---
10-20-80	1730	0530	A	10.5	10.5	NW	10-15	NW	0.6-1.0	OVERCAST	---
10-22-80	0920	1530	A	9.5	9.5	ENE	0-5	VAR	0-0.3	CLEAR	1.2
10-20-80	1735	0535	B	10.5	10.5	NW	10-15	NW	0.6-1.0	OVERCAST	---
10-22-80	0915	1337	B	10.7	10.0	VAR	0-5	VAR	0-0.3	CLEAR	1.5

Appendix 2. Continued.

STARTING DATE	TIME START	TIME FINISH	STATION	TEMPERATURE C SURFACE	TEMPERATURE C FISH DEPTH	WIND DIR. FROM	WIND SPEED MPH	WAVES DIR. FROM	WAVES HT. (M)	WEATHER	SECCHI DISC (M)
10-20-80	1748	0548	C	10.5	10.5	NW	15-20	NW	0.6-1.0	OVERCAST	---
10-22-80	0905	1347	C	10.7	11.0	VAR	0-5	VAR	0-0.3	CLEAR	1.75
10-22-80	0900	1342	C*	10.7	10.7	ENE	0-5	VAR	0-0.3	CLEAR	2.1
10-20-80	1748	0548	C*	10.7	10.5	NW	10-15	NW	0.6-1.0	OVERCAST	---
10-20-80	1757	0557	D	10.5	10.5	NW	10-15	NW	0.6-1.0	OVERCAST	---
10-22-80	0855	1354	D	11.0	11.0	ENE	0-10	VAR	0-0.3	CLEAR	2.5
10-20-80	1805	0605	E	10.5	10.5	NW	10-15	NW	0.6-1.0	OVERCAST	---
10-22-80	0845	1402	E	10.7	10.7	ENE	0-5	VAR	0-0.3	CLEAR	2.5
10-20-80	1815	0615	L	12.0	12.0	W	15-20	W	0.6-1.0	PT CLOUDY	---
10-22-80	0940	1555	L	11.0	10.7	VAR	0-5	VAR	0-0.3	CLEAR	2.8
10-22-80	0835	1550	L*	10.8	10.8	VAR	0-5	VAR	0-0.3	CLEAR	2.8
10-20-80	1800	0600	L*	12.0	12.0	W	15-20	W	0.6-1.0	PT CLOUDY	---
10-20-80	1730	0530	N	12.5	12.0	W	15-20	W	0.6-1.0	PT CLOUDY	---
10-22-80	0905	1530	N	11.0	11.3	VAR	0-5	VAR	0-0.3	CLEAR	2.8
10-20-80	1745	0545	U	11.5	11.5	W	15-20	W	0.6-1.0	PT CLOUDY	---
10-22-80	0900	1540	U	11.0	11.0	VAR	0-5	VAR	0-0.3	CLEAR	2.8
10-22-80	0945	1535	U*	11.0	11.0	VAR	0-5	VAR	0-0.3	CLEAR	2.8
10-20-80	1740	0540	U*	11.5	11.5	W	15-20	W	0.6-1.0	PT CLOUDY	---
11-05-80	0915	1505	A	7.3	7.3	NW	10-15	NW	0.6-1.0	PT CLOUDY	---
11-05-80	1755	0810	A	8.5	8.5	NW	10-15	NW	0.6-1.0	PT CLOUDY	---
11-05-80	0910	1510	B	7.0	7.0	NW	10-15	NW	0.6-1.0	PT CLOUDY	---
11-05-80	1748	0800	B	5.8	5.8	NW	10-15	NW	0.6-1.0	PT CLOUDY	---
11-05-80	0905	1515	C	7.0	7.0	NW	10-15	NW	0.6-1.0	PT CLOUDY	2.0
11-05-80	1740	0750	C	5.8	5.8	NW	10-15	NW	0.6-1.0	PT CLOUDY	---
11-05-80	0859	1525	C*	8.7	8.7	NW	10-15	NW	0.6-1.0	PT CLOUDY	2.0
11-05-80	1735	0755	C*	5.8	5.8	NW	10-15	NW	0.6-1.0	PT CLOUDY	---
11-05-80	0850	1520	D	9.3	9.3	NW	10-15	NW	0.6-1.0	PT CLOUDY	2.25
11-05-80	1720	0835	D	5.8	5.1	NW	10-15	NW	0.6-1.0	PT CLOUDY	---
11-05-80	0840	1530	E	9.3	9.3	NW	10-15	NW	0.6-1.0	PT CLOUDY	3.0
11-05-80	1727	0820	E	5.8	5.0	NW	10-15	NW	0.6-1.0	PT CLOUDY	---
11-05-80	1000	1545	L	8.7	8.7	NW	10-15	NW	0.6-1.0	PT CLOUDY	1.75
11-05-80	1735	0730	L	9.0	9.0	NW	10-15	NW	0.6-1.0	CLEAR	---
11-05-80	0950	1550	L*	8.7	8.7	NW	10-15	NW	0.6-1.0	PT CLOUDY	1.75
11-05-80	1730	0730	L*	9.0	9.0	NW	10-15	NW	0.6-1.0	CLEAR	---
11-05-80	1030	1630	N	8.5	8.5	NW	10-15	NW	0.6-1.0	PT CLOUDY	1.8
11-05-80	1700	0730	N	9.0	8.5	NW	10-15	NW	0.6-1.0	CLEAR	---
11-05-80	1010	1540	U	9.0	8.7	NW	10-15	NW	0.6-1.0	PT CLOUDY	1.75
11-05-80	1720	0740	U	5.0	5.0	NW	10-15	NW	1.0-2.0	CLEAR	---
11-05-80	1020	1525	U*	8.7	8.7	NW	10-15	NW	0.6-1.0	PT CLOUDY	1.75
11-05-80	1725	0750	U*	5.0	5.0	NW	10-15	NW	0.6-1.0	CLEAR	---

Appendix 3. Meteorological and limnological parameters measured during seining, April to November 1980 near the J. H. Campbell Plant, eastern Lake Michigan.

STARTING DATE	TIME		TEMPERATURE C		WIND		WAVES		WEATHER
	START	STATION	SURFACE	FISH DEPTH	DIR. FROM	SPEED MPH	DIR. FROM	HT. (M)	
4-22-80	1518	P	12.3	12.0	SW	10-15	SW	0.3-0.6	CLEAR
4-22-80	2015	P	12.1	12.0	SW	10-15	SW	0.3-0.6	CLEAR
4-22-80	1555	Q	10.3	10.0	SW	10-15	SW	0.3-0.6	CLEAR
4-22-80	2057	Q	9.3	9.0	SW	10-15	SW	0.3-0.5	CLEAR
4-22-80	1615	R	10.9	10.9	SW	10-15	SW	0.3-0.6	CLEAR
4-22-80	2108	R	9.6	9.6	SW	10-15	SW	0.3-0.6	CLEAR
5-20-80	1230	P	9.0	8.7	N	0-5	NW	0-0.3	CLEAR
5-20-80	2115	P	10.5	10.5	N	0-5	NW	0-0.3	CLEAR
5-20-80	1300	Q	10.6	10.2	CALM	0-5	NW	0-0.3	CLEAR
5-20-80	2150	Q	10.3	10.3	N	0-5	NW	0-0.3	CLEAR
5-20-80	1345	R	11.0	10.4	NW	0-5	NW	0-0.3	CLEAR
5-20-80	2221	R	11.0	11.0	N	0-5	NW	0-0.3	CLEAR
6-16-80	1350	P	15.0	15.0	WNW	10-15	NW	0.3-0.6	CLEAR
6-16-80	2305	P	10.5	10.5	NE	0-5	NW	0-0.3	CLEAR
6-16-80	1450	Q	14.5	14.5	WNW	10-15	NW	0.3-0.5	CLEAR
6-17-80	0003	Q	11.0	11.0	NE	0-5	NW	0-0.3	CLEAR
6-16-80	1530	R	15.5	15.5	WNW	10-15	NW	0.3-0.6	CLEAR
6-17-80	0105	R	11.5	11.5	SE	0-5	NW	0-0.3	CLEAR
7-14-80	1450	P	22.4	22.4	SW	10-15	SW	0.3-0.6	PT CLOUDY
7-14-80	2230	P	21.5	21.5	SW	15-20	SW	0.6-1.0	CLEAR
7-14-80	1455	Q	22.2	22.2	SW	15-20	SW	0.3-0.6	PT CLOUDY
7-14-80	2310	Q	21.4	21.4	SW	20-25	SW	0.6-1.0	CLEAR
7-14-80	1545	R	22.6	22.6	SW	10-15	NW	0.3-0.6	PT CLOUDY
7-15-80	0001	R	21.6	21.6	SW	20-25	SW	2-3	CLEAR
8-19-80	1315	P	20.2	20.2	SW	0-5	SW	0.3-0.6	CLEAR
8-20-80	2025	P	21.9	21.9	VAR	0-5	W	0-0.3	CLEAR
8-19-80	1400	Q	21.0	21.0	SW	0-5	SW	0.3-0.6	CLEAR
8-20-80	2110	Q	22.5	22.5	VAR	0-5	W	0-0.3	CLEAR
8-19-80	1432	R	21.3	21.3	SW	0-5	SW	0.3-0.6	CLEAR
8-20-80	2125	R	22.7	22.7	VAR	0-5	W	0-0.3	CLEAR
9-15-80	1705	P	17.9	17.9	E	0-5	W	0-0.3	OVERCAST
9-15-80	2040	P	18.2	18.2	S	5-10	S	0-0.3	OVERCAST
9-15-80	1740	Q	17.0	17.0	SE	0-5	VAR	0.3-0.6	OVERCAST
9-15-80	2000	Q	16.3	16.3	SE	0-5	W	0.3-0.6	OVERCAST
9-15-80	1805	R	17.3	17.3	E	5-10	VAR	0-0.3	OVERCAST
9-15-80	1940	R	16.5	16.5	SE	0-5	VAR	0.3-0.6	OVERCAST
10-23-80	1210	P	11.0	11.0	SE	10-15	SW	0.3-0.6	PT CLOUDY
10-22-80	1840	P	11.1	11.1	VAR	0-5	VAR	0-0.3	CLEAR
10-23-80	1245	Q	10.5	10.5	SE	10-15	SW	0.3-0.6	PT CLOUDY
10-22-80	1915	Q	11.0	11.0	VAR	0-5	VAR	0-0.3	CLEAR
10-23-80	1315	R	10.8	10.8	SE	10-15	SW	0.3-0.6	PT CLOUDY
10-22-80	1940	R	11.2	11.2	SE	0-5	VAR	0-0.3	CLEAR
11-07-80	1615	P	9.0	9.0	N	0-5	VAR	0-0.3	OVERCAST
11-07-80	1920	P	7.3	7.3	NW	15-20	NW	0.6-1.0	CLEAR
11-05-80	1955	Q	7.3	7.3	NW	10-15	NW	0.6-1.0	CLEAR
11-07-80	1700	Q	8.5	8.5	N	10-15	N	0.6-1.0	OVERCAST
11-07-80	1645	R	8.7	8.7	N	10-15	N	0.3-0.6	OVERCAST
11-07-80	2014	R	7.3	7.3	NW	10-15	NW	0.6-1.0	CLEAR

Appendix 4. Meteorological and limnological parameters measured during trawling, April to December 1980 near the J. H. Campbell Plant, eastern Lake Michigan.

STARTING DATE	TIME		STATION	TEMPERATURE C		WIND		WAVES		WEATHER	SECCHI DISC (M)
	START	FINISH		SURFACE	FISH DEPTH	DIR. FROM	SPEED MPH	DIR. FROM	HT. (M)		
4-25-80	2010	2020	B	7.0	7.0	NW	5-10	NW	0.3-0.6	CLEAR	---
4-25-80	1610	1620	C	6.4	6.4	NW	5-10	NW	0.6-1.0	CLEAR	2.0
4-25-80	2045	2055	C	6.5	6.5	NW	5-10	NW	0.3-0.6	CLEAR	---
4-25-80	1645	1655	D	6.5	6.5	NW	10-15	NW	0.3-0.6	CLEAR	2.0
4-25-80	2120	2130	D	6.6	6.5	NW	5-10	NW	0.3-0.6	CLEAR	---
4-25-80	1725	1735	E	6.5	6.4	NW	5-10	NW	0.3-0.6	CLEAR	2.0
4-25-80	2200	2210	F	6.5	6.3	NW	5-10	NW	0.3-0.6	PT CLOUDY	---
4-25-80	1805	1815	F	4.9	4.8	WSW	0-5	NW	0.3-0.6	CLEAR	3.0
4-25-80	2245	2255	F	5.1	5.1	WNW	10-15	NW	0-0.3	OVERCAST	---
4-24-80	1345	1355	L	7.2	7.2	NW	20-25	NW	0.6-1.0	OVERCAST	1.75
4-26-80	0020	0030	L	7.2	7.0	NW	10-15	NW	0-0.3	OVERCAST	---
4-24-80	1305	1315	N	6.3	6.2	NW	20-25	NW	0.6-1.0	OVERCAST	2.0
4-25-80	2340	2350	N	6.5	6.5	NW	5-10	NW	0-0.3	OVERCAST	---
5-21-80	1512	1522	B	12.0	7.6	W	0-5	NW	0-0.3	CLEAR	BOTTOM
5-21-80	2051	2101	B	9.6	7.5	CALM	0-5	CALM	0-0.3	CLEAR	---
5-21-80	1545	1555	C	11.2	6.6	VAR	0-5	NW	0-0.3	CLEAR	3.0
5-21-80	2128	2138	C	11.4	6.5	CALM	0-5	CALM	0-0.3	CLEAR	---
5-21-80	1625	1635	D	11.5	6.4	VAR	0-5	NW	0-0.3	CLEAR	3.1
5-21-80	2208	2218	D	8.0	6.0	CALM	0-5	CALM	0-0.3	CLEAR	---
5-21-80	1707	1717	E	11.5	6.0	W	0-5	CALM	0-0.3	CLEAR	3.0
5-21-80	2250	2300	E	11.0	6.0	S	5-10	SW	0-0.3	CLEAR	---
5-21-80	1751	1801	F	11.5	5.5	CALM	0-5	CALM	0-0.3	CLEAR	3.0
5-21-80	2331	2341	F	11.1	5.5	W	0-5	CALM	0-0.3	CLEAR	---
5-21-80	1326	1336	L	11.0	7.2	NW	5-10	NW	0-0.3	CLEAR	3.0
5-22-80	0119	0129	L	10.8	6.6	CALM	0-5	CALM	0-0.3	CLEAR	---
5-21-80	1405	1415	N	11.0	6.5	VAR	0-5	NW	0-0.3	CLEAR	3.5
5-22-80	0040	0050	N	10.5	6.1	VAR	0-5	CALM	0-0.3	CLEAR	---
6-17-80	1726	1736	B	14.5	14.5	SW	5-10	SW	0-0.3	CLEAR	1.5
6-17-80	2344	2354	B	13.5	13.5	S	10-15	SW	0.3-0.6	CLEAR	---
6-17-80	1621	1631	C	12.3	13.2	S	10-15	SW	0.3-0.6	CLEAR	---
6-17-80	2306	2316	C	12.3	12.3	S	10-15	SW	0.3-0.6	CLEAR	---
6-17-80	1539	1549	D	13.7	12.1	SW	0-5	SW	0.3-0.6	CLEAR	3.0
6-17-80	2224	2234	D	12.4	11.8	S	10-15	SW	0.3-0.6	CLEAR	---
6-17-80	1500	1510	E	13.3	10.7	SW	0-5	SW	0.3-0.6	CLEAR	3.25
6-17-80	2146	2156	F	13.0	9.5	S	10-15	SW	0.3-0.6	CLEAR	---
6-17-80	1413	1423	F	14.0	8.8	SW	5-10	SW	0.3-0.6	CLEAR	3.5
6-17-80	2056	2106	F	13.0	7.9	SW	0-5	SW	0.3-0.6	CLEAR	---
6-17-80	1317	1327	L	13.0	11.5	SW	0-5	SW	0.3-0.6	CLEAR	2.5
6-18-80	0111	0121	L	14.7	14.6	VAR	0-5	SW	0.3-0.6	CLEAR	---
6-17-80	1238	1248	N	13.2	10.3	SW	10-15	SW	0.3-0.6	CLEAR	2.0
6-18-80	0036	0046	N	14.4	13.9	SW	0-5	SW	0.3-0.6	CLEAR	---
7-15-80	2359	0009	B	22.0	22.0	CALM	0-5	VAR	0-0.3	CLEAR	---
7-15-80	1805	1815	C	22.0	21.4	VAR	5-10	SW	0.6-1.0	CLEAR	2.0
7-15-80	2315	2325	C	21.5	20.8	VAR	0-5	VAR	0-0.3	CLEAR	---
7-15-80	1725	1735	D	20.6	20.6	VAR	5-10	SW	0.6-1.0	CLEAR	3.0

Appendix 4. Continued.

STARTING DATE	TIME START	TIME FINISH	STATION	TEMPERATURE C SURFACE	TEMPERATURE C FISH DEPTH	WIND DIR. FROM	WIND SPEED MPH	WAVES DIR. FROM	WAVES HT. (M)	WEATHER	SECCHI DISC (M)
7-15-80	2235	2245	D	22.1	23.0	CALM	0-5	VAR	0-0.3	CLEAR	---
7-15-80	1645	1655	E	21.0	16.3	VAR	5-10	SW	0.6-1.0	CLEAR	3.0
7-15-80	2150	2200	E	20.1	19.0	CALM	0-5	VAR	0-0.3	CLEAR	---
7-15-80	1558	1608	F	20.5	16.0	VAR	5-10	SW	0.6-1.0	PT CLOUDY	4.6
7-15-80	2105	2115	F	20.5	19.3	VAR	0-5	VAR	0.3-0.6	CLEAR	---
7-15-80	1503	1513	L	21.0	21.3	SW	10-15	SW	0.6-1.0	PT CLOUDY	2.0
7-16-80	0126	0136	L	20.8	21.0	E	0-5	VAR	0-0.3	OVERCAST	---
7-15-80	1402	1412	N	20.8	17.5	SW	5-10	SW	0.6-1.0	PT CLOUDY	3.0
7-15-80	0047	0057	N	20.2	20.4	VAR	0-5	VAR	0-0.3	OVERCAST	---
8-19-80	1820	1830	B	19.8	19.8	S	5-10	SW	0.3-0.6	CLEAR	BOTTOM
8-19-80	2256	2306	B	19.5	19.0	VAR	5-10	SW	0.3-0.6	PT CLOUDY	---
8-19-80	1517	1527	C	23.0	23.0	S	10-15	SW	0.6-1.0	PT CLOUDY	4.0
8-19-80	2220	2230	C	19.0	17.5	VAR	5-10	SW	0.3-0.6	PT CLOUDY	---
8-19-80	1553	1603	D	21.0	18.0	S	10-15	SW	0.6-1.0	PT CLOUDY	5.0
8-19-80	2140	2150	D	19.5	10.5	VAR	5-10	SW	0.3-0.6	PT CLOUDY	---
8-19-80	1638	1648	E	20.0	9.0	S	5-10	SW	0.6-1.0	PT CLOUDY	5.5
8-19-80	2057	2107	E	20.0	9.0	S	5-10	SW	0.3-0.6	PT CLOUDY	---
8-19-80	1727	1737	F	19.5	7.0	S	5-10	SW	0.6-1.0	PT CLOUDY	5.0
8-18-80	2009	2019	F	19.5	7.5	S	0-5	SW	0.3-0.6	PT CLOUDY	---
8-19-80	1423	1433	L	20.0	19.0	SW	5-10	SW	0.6-1.0	PT CLOUDY	3.5
8-20-80	0027	0037	L	19.0	12.5	SE	15-20	SW	0.3-0.6	OVERCAST	---
8-19-80	1345	1355	N	19.5	17.5	SW	5-10	SW	0.6-1.0	CLEAR	5.5
8-19-80	2348	2358	N	19.0	10.0	E	10-15	S	0.3-0.6	OVERCAST	---
9-17-80	0837	0847	C	12.0	13.0	NE	5-10	ENE	1-2	PT CLOUDY	2.5
9-17-80	0237	0247	C	15.5	15.2	N	25+	NW	2-3	OVERCAST	---
9-17-80	0938	0948	D	16.8	11.0	NE	0-5	NE	1-2	CLEAR	2.0
9-17-80	0328	0338	D	17.4	11.0	NE	20-25	NE	1-2	OVERCAST	---
9-17-80	1021	1031	E	17.0	10.7	VAR	0-5	NE	0.6-1.0	CLEAR	3.5
9-17-80	0410	0420	E	17.4	7.3	NE	15-20	NE	1-2	OVERCAST	---
9-17-80	1113	1123	F	17.0	7.5	N	5-10	N	1-2	CLEAR	2.5
9-17-80	0452	0502	F	17.4	6.8	NE	15-20	NE	1-2	OVERCAST	---
9-17-80	1304	1314	L	18.0	13.5	N	20-25	N	2-3	CLEAR	2.0
9-17-80	0143	0153	L	21.0	21.0	NE	15-20	NE	1-2	OVERCAST	---
9-17-80	1223	1233	N	22.2	18.5	N	20-25	N	2-3	CLEAR	2.0
9-17-80	0058	0108	N	21.2	21.0	NE	15-20	NE	1-2	OVERCAST	---
10-22-80	1016	1026	B	10.5	10.2	ESE	5-10	SE	0-0.3	CLEAR	1.25
10-21-80	2010	2020	B	11.0	11.0	NW	10-15	NW	0.6-1.0	PT CLOUDY	---
10-22-80	1051	1101	C	11.0	10.8	ESE	10-15	SE	0-0.3	CLEAR	1.75
10-21-80	2045	2055	C	11.3	11.3	N	15	NW	0.6-1.0	PT CLOUDY	---
10-22-80	1129	1139	D	11.8	11.8	ESE	10-15	SE	0-0.3	CLEAR	3.0
10-21-80	2120	2130	D	11.5	11.8	N	15	NW	0.6-1.0	PT CLOUDY	---
10-22-80	1247	1257	F	12.2	12.0	VAR	0-5	SE	0-0.3	CLEAR	3.0
10-21-80	2200	2210	E	12.0	12.0	N	15-20	NW	0.6-1.0	PT CLOUDY	---
10-22-80	1326	1336	F	12.5	12.2	VAR	0-5	VAR	0-0.3	CLEAR	3.0
10-21-80	2245	2255	F	12.0	11.9	NNW	12-25	NW	0.6-1.0	PT CLOUDY	---

Appendix 4. Continued.

STARTING DATE	TIME START	TIME FINISH	STATION	TEMPERATURE C SURFACE	TEMPERATURE C FISH DEPTH	WIND DIR. FROM	WIND SPEED MPH	WAVES DIR. FROM	WAVES HT. (M)	WEATHER	SECCHI DISC (M)
10-22-80	0920	0930	L	11.0	11.2	ESE	10	SE	0-0.3	CLEAR	2.5
10-21-80	1918	1928	L	11.2	12.0	NW	5-10	NW	0.6-1.0	PT CLOUDY	---
10-22-80	0842	0852	N	11.0	11.0	ESE	10	SE	0-0.3	CLEAR	3.0
10-21-80	1837	1847	N	11.5	12.0	NW	5-10	NW	0.6-1.0	PT CLOUDY	---
11-05-80	1250	1300	C	5.4	5.8	NW	20	NW	1-2	PT CLOUDY	1.75
11-05-80	1845	1855	C	5.4	5.8	NW	10-15	NW	0.6-1.0	PT CLOUDY	---
11-05-80	1335	1345	D	5.1	5.1	NW	20	NW	1-2	PT CLOUDY	2.25
11-05-80	1925	1935	D	5.0	5.1	NW	10-15	NW	0.6-1.0	PT CLOUDY	---
11-05-80	1420	1430	E	5.1	5.1	NW	20	NW	1-2	PT CLOUDY	2.75
11-05-80	2005	2015	E	5.0	5.0	NW	10-15	NW	0.6-1.0	PT CLOUDY	---
11-05-80	1500	1510	F	5.2	5.9	NW	20-25	NW	1-2	PT CLOUDY	2.5
11-05-80	2045	2055	F	5.0	5.2	NW	10-15	NW	0.6-1.0	PT CLOUDY	---
11-05-80	1130	1140	L	5.2	6.0	NNW	15-20	NW	1-2	PT CLOUDY	1.75
11-05-80	2225	2235	L	5.0	5.0	W	15-20	NW	0.6-1.0	PT CLOUDY	---
11-05-80	1050	1100	N	5.5	5.8	NNW	15-20	NW	1-2	PT CLOUDY	1.8
11-05-80	2145	2155	N	5.3	5.3	W	10-15	NW	0.6-1.0	PT CLOUDY	---
12-01-80	1236	1246	B	4.5	4.5	NE	0-5	NW	0.6-1.0	OVERCAST	1.5
12-01-80	1745	1755	B	4.1	4.1	NE	10-15	NW	0.4	OVERCAST	---
12-01-80	1252	1302	C	4.7	5.0	NE	0-5	NW	0.6-1.0	OVERCAST	1.9
12-01-80	1819	1829	C	4.5	4.5	NE	10-15	NW	0.4	OVERCAST	---
12-01-80	1328	1338	D	5.0	4.7	N	10	NW	0.6-1.0	OVERCAST	2.0
12-01-80	1855	1905	D	4.5	4.3	NE	10-15	NW	0.4	OVERCAST	---
12-01-80	1408	1418	E	5.0	4.9	N	5-10	NW	0.6-1.0	PT CLOUDY	2.1
12-01-80	1938	1948	F	4.5	4.5	E	10	N	0.3-0.6	OVERCAST	---
12-01-80	1450	1500	F	5.2	5.0	N	15-20	NW	0.6-1.0	OVERCAST	2.0
12-01-80	2017	2027	F	5.0	4.9	E	10-15	N	0.3-0.6	OVERCAST	---
12-01-80	1110	1120	L	5.5	5.3	NE	0-5	NW	0.7	OVERCAST	2.0
12-01-80	2157	2207	L	5.1	5.0	NE	15-20	N	0.3	OVERCAST	---
12-01-80	1028	1038	N	5.6	5.2	NE	0-5	NW	0.7	OVERCAST	2.1
12-01-80	2118	2128	N	5.1	5.0	NE	15-20	N	0.3	OVERCAST	---

Appendix 5. Meteorological and limnological parameters measured during fish larvae sampling by plankton net, April to September 1980 near the J. H. Campbell Plant, eastern Lake Michigan.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
4-21-80	1605	A	D	2.0	SURFACE	7.5	SSE	0-5	S	0-0.1	HAZE
					MID-DEPTH	7.0					
					BOTTOM	7.0					
4-21-80	2305	A	N	-	SURFACE	7.5	SSE	10-15	SE	0-0.5	CLEAR
					MID-DEPTH	7.5					
					BOTTOM	7.5					
4-21-80	1557	B	D	2.0	SURFACE	6.9	SSE	10-15	SE	0-0.5	CLEAR
					MID-DEPTH	6.9					
					BOTTOM	6.9					
4-21-80	2256	B	N	-	SURFACE	6.7	SSE	10-15	SE	0-0.3	CLEAR
					MID-DEPTH	6.7					
					BOTTOM	6.7					
4-22-80	1233	C	D	1.5	0.5	7.0	S	10-15	SW	1.0	HAZE
					2.0	7.0					
					4.0	6.9					
					5.5	6.9					
4-21-80	2010	C	N	-	0.5	6.0	S	10-15	S	1.0	CLEAR
					2.0	6.0					
					4.0	6.0					
					5.5	5.8					
4-22-80	1309	D	D	2.5	0.5	4.5	S	10-15	SSW	1.0	HAZE
					2.5	4.5					
					4.5	4.4					
					6.5	4.4					
					8.5	4.4					
4-21-80	2021	D	N	-	0.5	4.5	CALM	CALM	CALM	CALM	CLEAR
					2.5	4.5					
					4.5	4.4					
					6.5	4.4					
					8.5	4.4					
					9.0	4.4					
					11.0	4.4					
4-21-80	2102	F	N	-	0.5	4.2	ENE	0-5	ENE	CALM	CLEAR
					3.0	4.2					
					6.0	4.3					
					9.0	4.4					
					11.0	4.4					
4-22-80	1427	F	D	3.0	0.5	4.0	S	10-15	SSW	0.6	HAZE
					4.5	4.0					
					8.5	4.0					
					11.5	4.0					
					14.0	4.0					
4-21-80	2140	F	N	-	0.5	3.5	ENE	0-5	ENE	CALM	CLEAR
					4.5	3.5					
					8.5	4.1					
					11.5	4.1					
					14.0	4.1					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
4-21-80	1528	I	D	BOTTOM	SURFACE	7.7	SSE	0-5	SSE	CALM	HAZE
					MID-DEPTH	7.5					
					BOTTOM	7.0					
4-21-80	2333	I	N	-	SURFACE	6.7	SSE	10-15	SE	0-0.3	CLEAR
					MID-DEPTH	6.7					
					BOTTOM	6.7					
4-21-80	1534	J	D	2.0	SURFACE	6.6	SSE	0-5	SSE	CALM	CLEAR
					MID-DEPTH	6.4					
					BOTTOM	5.8					
4-22-80	0003	J	N	-	SURFACE	6.5	SSE	10-15	SE	0-0.5	CLEAR
					MID-DEPTH	6.5					
					BOTTOM	6.5					
4-22-80	1643	L	D	2.0	0.5	6.0	S	15-20	S	0.6	HAZE
					2.0	7.0					
					4.0	7.0					
4-22-80	0028	L	N	-	0.5	5.2	SSE	15-20	SE	0.3	CLEAR
					2.0	5.2					
					4.0	5.2					
4-22-80	1633	N	D	2.0	0.5	5.5	S	15-20	S	0.6	HAZE
					2.5	6.0					
					4.5	6.1					
					6.5	6.0					
					8.5	5.8					
4-21-80	2350	N	N	-	0.5	4.2	SE	15-20	SE	0.3	CLEAR
					2.5	4.2					
					4.5	4.2					
					6.5	4.2					
					8.5	4.2					
4-22-80	1554	O	D	3.5	0.5	4.5	S	10-15	S	0.6	HAZE
					3.0	4.5					
					6.0	4.5					
					9.0	4.6					
					11.0	4.6					
4-21-80	2310	O	N	-	0.5	4.2	SE	10-15	SE	0.3	CLEAR
					3.0	4.2					
					6.0	4.1					
					9.0	4.1					
					11.0	4.1					
4-22-80	1526	P	D	BOTTOM	SURFACE	12.3	SW	5-10	SW	0.3-0.6	CLEAR
					BOTTOM	12.0					
4-22-80	2108	P	N	-	SURFACE	12.0	SW	10-15	SW	0.6-1.0	CLEAR
					BOTTOM	12.0					
4-22-80	1555	Q	D	-	SURFACE	10.3	SW	10-15	SW	0.3-0.6	HAZE
					BOTTOM	10.1					
4-22-80	2057	Q	N	-	SURFACE	9.3	SW	10-15	SW	0.6-1.0	CLEAR
					BOTTOM	9.0					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
4-22-80	1620	R	D	-	SURFACE	10.9	SW	10-15	SW	0.3-0.6	HAZE
					BOTTOM	10.9					
4-22-80	2108	R	N	-	SURFACE	9.6	SW	10-15	SW	0.6-1.0	CLEAR
					BOTTOM	9.6					
4-22-80	1518	W	D	3.5	0.5	3.0	S	10-15	S	0.6	HAZE
					4.5	3.0					
					8.5	3.1					
					11.5	3.1					
					14.0	3.1					
4-21-80	2233	W	N	-	0.5	4.5	SE	5-10	SE	0.1	CLEAR
					4.5	4.3					
					8.5	4.1					
					11.5	4.0					
					14.0	3.9					
5-19-80	1556	A	D	BOTTOM	SURFACE	10.0	VAR	0-5	VAR	0.3	HAZE
					MID-DEPTH	10.0					
					BOTTOM	10.0					
5-19-80	2324	A	N	-	SURFACE	9.3	E	0-5	VAR	0.3	PT. CLOUDY
					MID-DEPTH	8.2					
					BOTTOM	8.2					
5-19-80	1540	B	D	2.0	SURFACE	9.6	VAR	0-5	NW	0-0.3	HAZE
					MID-DEPTH	9.6					
					BOTTOM	9.6					
5-19-80	2306	B	N	-	SURFACE	8.3	E	0-5	VAR	0.3	PT. CLOUDY
					MID-DEPTH	7.2					
					BOTTOM	7.2					
5-20-80	1258	C	D	3.5	0.5	9.0	NW	5-10	NW	0.1	PT. CLOUDY
					2.0	8.2					
					4.0	7.4					
					5.5	5.8					
5-19-80	2036	C	N	-	0.5	10.5	VAR	5-10	VAR	0-0.3	PT. CLOUDY
					2.0	10.4					
					4.0	9.7					
					5.5	9.2					
5-20-80	1335	D	D	3.0	0.5	10.5	NW	5-10	NW	0.1	PT. CLOUDY
					2.5	9.5					
					4.5	8.0					
					6.5	6.5					
					8.5	6.5					
5-19-80	2115	D	N	-	0.5	7.8	VAR	5-10	VAR	0-0.3	CLEAR
					2.5	7.7					
					4.5	7.5					
					6.5	6.2					
					8.5	5.3					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
5-20-80	1412	F	D	2.5	0.5	9.5	NW	10-15	NW	0.1	PT. CLOUDY
					3.0	8.3					
					6.0	5.2					
					9.0	5.1					
					11.0	5.1					
5-19-80	2157	F	N	-	SURFACE	8.5	VAR	0-5	CALM	0-0.3	CLEAR
					MID-DEPTH	8.4					
					BOTTOM	5.5					
5-20-80	1451	F	D	2.7	0.5	10.2	NW	10-15	NW.	0.3	PT. CLOUDY
					4.5	9.6					
					8.5	6.6					
					11.5	5.8					
					14.0	5.7					
5-19-80	2240	F	N	-	SURFACE	8.6	VAR	0-5	CALM	0-0.3	CLEAR
					MID-DEPTH	6.6					
					BOTTOM	5.2					
5-19-80	1606	I	D	BOTTOM	SURFACE	11.0	NNE	5-10	NW	0-0.3	PT. CLOUDY
					MID-DEPTH	10.7					
					BOTTOM	10.0					
5-19-80	2259	I	N	-	SURFACE	9.6	E	0-5	CALM	CALM	CLEAR
					MID-DEPTH	9.6					
					BOTTOM	9.6					
5-19-80	1545	J	D	2.5	SURFACE	9.0	NNE	5-10	NW	0-0.3	PT. CLOUDY
					MID-DEPTH	9.0					
					BOTTOM	8.5					
5-19-80	2238	J	N	-	SURFACE	9.2	E	0-5	CALM	CALM	CLEAR
					MID-DEPTH	8.6					
					BOTTOM	8.6					
5-20-80	1756	L	D	2.8	0.5	9.0	NNE	0-5	NW	0-0.5	CLEAR
					2.0	8.9					
					4.0	7.8					
					5.5	6.9					
5-20-80	0139	L	N	-	SURFACE	8.7	VAR	0-5	VAR	0-0.3	PT. CLOUDY
					MID-DEPTH	8.5					
					BOTTOM	7.3					
5-20-80	1714	N	D	2.7	0.5	10.1	NNW	0-5	NW	0-0.5	HAZE
					2.5	10.2					
					4.5	9.3					
					6.5	7.1					
					8.5	6.8					
5-20-80	0100	N	N	-	SURFACE	6.8	VAR	0-5	NW	0-0.3	PT. CLOUDY
					MID-DEPTH	6.1					
					BOTTOM	6.1					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
5-20-80	1639	O	D	2.5	0.5	10.4	NNW	5-10	NW	0-0.3	PT. CLOUDY
					3.0	10.0					
					6.0	8.2					
					9.0	6.8					
					11.0	6.3					
5-20-80	0020	O	N	-	SURFACE	9.3	CALM	0-5	CALM	CALM	CLEAR
					MID-DEPTH	8.2					
					BOTTOM	6.0					
5-19-80	1245	P	D	BOTTOM	SURFACE	9.0	VAR	0-5	NW	0-0.3	HAZE
					MID-DEPTH	8.7					
					BOTTOM	8.7					
5-19-80	2110	P	N	-	SURFACE	10.5	E	0-5	VAR	0.3	PT. CLOUDY
					MID-DEPTH	10.5					
					BOTTOM	10.5					
5-20-80	1320	Q	D	-	SURFACE	10.6	NW	0-5	NW	0.3	CLEAR
					MID-DEPTH	10.2					
					BOTTOM	10.2					
5-20-80	2150	Q	N	-	SURFACE	10.3	N	0-5	NW	0-0.3	CLEAR
					MID-DEPTH	10.3					
					BOTTOM	10.3					
5-20-80	1355	R	D	-	SURFACE	11.0	NW	0-5	NW	0.3	CLEAR
					MID-DEPTH	10.4					
					BOTTOM	10.4					
5-20-80	2221	R	N	-	SURFACE	11.0	N	0-5	NW	0-0.3	CLEAR
					MID-DEPTH	11.0					
					BOTTOM	11.0					
5-20-80	1553	W	D	2.5	0.5	10.3	NNW	5-10	NW	0-0.3	PT. CLOUDY
					4.5	8.9					
					8.5	8.2					
					11.5	7.3					
					14.0	6.0					
5-19-80	2340	W	N	-	SURFACE	8.0	VAR	0-5	NW	0-0.3	PT. CLOUDY
					MID-DEPTH	7.3					
					BOTTOM	5.7					
6-02-80	1703	A	D	BOTTOM	SURFACE	15.7	NW	0-5	NW	0-0.3	PT. CLOUDY
					MID-DEPTH	15.4					
					BOTTOM	15.1					
6-13-80	2344	A	N	-	SURFACE	15.5	NE	0-5	N	0-0.3	CLEAR
					MID-DEPTH	15.5					
					BOTTOM	13.3					
6-02-80	1640	B	D	2.7	SURFACE	15.5	NW	0-5	NW	0-0.3	PT. CLOUDY
					MID-DEPTH	15.0					
					BOTTOM	14.9					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
6-03-80	2318	B	N	-	SURFACE	15.0	NE	0-5	N	0-0.3	CLEAR
					MID-DEPTH	12.3					
					BOTTOM	10.3					
6-02-80	1238	C	D	3.0	0.5	14.2	SW	10-15	SW	0.2	OVERCAST
					2.0	14.1					
					4.0	14.1					
					5.5	14.0					
6-03-80	2127	C	N	-	0.5	14.3	NE	10-15	NW	0.3-0.6	CLEAR
					2.0	14.3					
					4.0	9.0					
					5.5	9.0					
6-02-80	1313	D	D	3.5	0.5	14.0	SW	10-15	SW	0.2	FOG
					2.5	13.9					
					4.5	13.8					
					6.5	13.7					
					8.5	13.6					
6-03-80	2206	D	N	-	0.5	13.9	NE	5-10	NW	0.4	CLEAR
					2.5	9.3					
					4.5	8.1					
					6.5	8.0					
					8.5	7.9					
6-02-80	1350	E	D	3.5	0.5	15.0	SW	5-10	SW	0.2	FOG
					3.0	14.8					
					6.0	14.8					
					9.0	14.7					
					11.0	14.6					
6-03-80	2244	E	N	-	0.5	13.9	NE	5-10	NW	0.3-0.6	CLEAR
					3.0	8.3					
					6.0	7.1					
					9.0	6.9					
					11.0	6.9					
6-02-80	1432	F	D	3.5	0.5	15.0	SSW	0-5	CALM	CALM	CLEAR
					4.5	14.9					
					8.5	14.7					
					11.5	14.6					
					14.0	14.6					
6-03-80	2327	F	N	-	0.5	13.9	VAR	0-5	NW	0.3-0.6	CLEAR
					4.5	8.9					
					8.5	6.6					
					11.5	6.5					
					14.0	6.4					
6-03-80	1158	I	D	2.0	SURFACE	11.2	NW	10-15	NW	1.3	CLEAR
					MID-DEPTH	8.5					
					BOTTOM	8.5					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
6-03-80	2307	I	N	-	SURFACE	14.0	NE	0-5	N	0-0.3	CLEAR
					MID-DEPTH	14.0					
					BOTTOM	14.0					
6-03-80	1135	J	D	2.25	SURFACE	11.0	NW	10-15	NW	1.3	CLEAR
					MID-DEPTH	7.5					
					BOTTOM	7.5					
6-03-80	2301	J	N	-	SURFACE	15.0	NE	0-5	N	0-0.3	CLEAR
					MID-DEPTH	14.0					
					BOTTOM	9.9					
6-02-80	1722	L	D	3.0	0.5	15.3	VAR	0-5	NW.	0-0.1	CLEAR
					2.0	15.0					
					4.0	14.8					
					5.5	14.8					
6-04-80	0227	L	N	-	0.5	9.8	VAR	0-5	NW	0.3	CLEAR
					2.0	7.7					
					4.0	6.2					
					5.5	6.2					
6-02-80	1641	N	D	3.25	0.5	15.5	VAR	CALM	CALM	CALM	HAZE
					2.5	15.2					
					4.5	14.9					
					6.5	14.9					
					8.5	14.7					
6-04-80	0147	N	N	-	0.5	13.9	VAR	0-5	NW	0.3	CLEAR
					2.5	8.1					
					4.5	7.1					
					6.5	7.0					
					8.5	6.9					
6-02-80	1605	O	D	3.0	0.5	16.5	VAR	0-5	CALM	CALM	PT. CLOUDY
					3.0	15.8					
					6.0	15.7					
					9.0	15.5					
					11.0	15.4					
6-04-80	0109	O	N	-	0.5	13.9	VAR	0-5	NW	0.3	CLEAR
					3.0	8.0					
					6.0	6.4					
					9.0	6.4					
					11.0	6.4					
6-02-80	1725	P	D	BOTTOM	SURFACE	16.8	NW	0-5	NW	0-0.3	PT. CLOUDY
					BOTTOM	16.5					
6-04-80	0010	P	N	-	SURFACE	13.8	NE	0-5	N	0-0.3	CLEAR
					MID-DEPTH	11.5					
					BOTTOM	11.5					
6-03-80	1045	O	D	-	SURFACE	15.8	NW	10-15	NW	1.3	CLEAR
					BOTTOM	15.7					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
6-04-80	0030	Q	N	-	SURFACE	15.0	NE	0-5	N	0-0.3	CLEAR
					MID-DEPTH	13.5					
					BOTTOM	13.5					
6-03-80	1115	R	D	-	SURFACE	16.7	NW	10-15	NW	1.3	CLEAR
					BOTTOM	16.7					
6-03-80	2350	R	N	-	SURFACE	15.7	NE	0-5	N	0-0.5	CLEAR
					MID-DEPTH	14.0					
					BOTTOM	14.0					
6-02-80	1523	W	D	3.0	0.5	16.8	VAR	0-5	CALM	CALM	CLEAR
					4.5	16.6					
					8.5	16.5					
					11.5	16.4					
					14.0	16.1					
6-04-80	0024	W	N	-	0.5	13.8	VAR	0-5	NW	0.3	CLEAR
					4.5	7.0					
					8.5	5.7					
					11.5	5.7					
					14.0	5.6					
6-16-80	1445	A	D	.75	SURFACE	13.0	NW	15-20	NW	0.8	CLEAR
					MID-DEPTH	13.0					
					BOTTOM	13.0					
6-16-80	0018	A	N	-	SURFACE	10.5	N	10-15	NW	0-1	CLEAR
					MID-DEPTH	10.5					
					BOTTOM	10.5					
6-16-80	1422	B	D	2.0	SURFACE	10.7	NW	15-20	NW	0.8	CLEAR
					MID-DEPTH	10.5					
					BOTTOM	10.5					
6-16-80	2357	B	N	-	SURFACE	11.0	N	10-15	NW	0-1	CLEAR
					MID-DEPTH	10.5					
					BOTTOM	9.5					
6-17-80	1618	C	D	2.75	0.5	13.6	VAR	0-5	SW	0-0.3	CLEAR
					2.0	13.5					
					4.0	13.3					
					5.5	13.2					
6-17-80	2304	C	N	-	SURFACE	12.3					
					MID-DEPTH	12.3					
					BOTTOM	12.3					
6-17-80	1549	D	D	3.0	0.5	13.7	VAR	0-5	SW	0-0.3	CLEAR
					2.5	13.3					
					4.5	13.2					
					6.5	12.9					
					8.5	12.1					
6-17-80	2235	D	N	-	0.5	12.4	S	10-15	SW	0.6	CLEAR

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
6-17-80	1502	E	D	3.25	0.5	13.3	VAR	0-5	SW	0-0.3	CLEAR
					3.0	12.2					
					6.0	11.4					
					9.0	10.7					
					11.0	10.7					
6-17-80	2156	E	N	-	0.5	13.0	S	10-15	SW	0.6	CLEAR
					3.0	13.0					
					6.0	11.6					
					9.0	9.9					
					11.0	9.6					
6-17-80	1422	F	D	3.5	0.5	14.0	VAR	0-5	SW	0-0.3	CLEAR
					4.5	12.4					
					8.5	9.6					
					11.5	8.9					
					14.0	8.8					
6-17-80	2236	F	N	-	0.5	13.0	S	10-15	SW	0.6	CLEAR
					4.5	12.2					
					8.5	10.0					
					11.5	8.1					
					14.0	7.9					
6-16-80	1440	I	D	1.0	SURFACE	13.0	NW	15-20	NW	0.3-0.6	CLEAR
					MID-DEPTH	12.5					
					BOTTOM	12.5					
6-17-80	0012	I	N	-	SURFACE	11.5	VAR	0-5	CALM	CALM	HAZE
					MID-DEPTH	11.5					
					BOTTOM	11.5					
6-16-80	1416	J	D	1.5	SURFACE	10.7	NW	15-20	NW	0.3-0.6	CLEAR
					MID-DEPTH	10.7					
					BOTTOM	10.7					
6-16-80	2352	J	N	-	SURFACE	11.5	VAR	0-5	CALM	CALM	HAZE
					MID-DEPTH	9.0					
					BOTTOM	9.0					
6-17-80	1315	L	D	2.5	0.5	13.0	SW	5-10	SW	0.3-0.6	CLEAR
					2.0	12.9					
					4.0	12.3					
					5.5	11.5					
6-18-80	2237	L	N	-	0.5	14.2	CALM	VAR	CALM	0.3-0.6	PT. CLOUDY
					2.0	14.2					
					4.0	14.2					
					5.5	14.1					
6-17-80	1234	N	D	2.0	0.5	13.2	SW	10-15	SW	0.3-0.6	CLEAR
					2.5	13.0					
					4.5	11.1					
					6.5	10.8					
					8.5	10.3					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
6-18-80	2157	N	N	-	0.5	14.4	CALM	VAR	CALM	0.3-0.6	PT. CLOUDY
					2.5	14.3					
					4.5	14.2					
					6.5	13.9					
					8.5	13.9					
6-17-80	1200	O	D	2.75	0.5	13.0	SW	10-15	SW	0.3-0.6	CLEAR
					3.0	12.8					
					6.0	11.0					
					9.0	8.7					
					11.0	8.6					
6-18-80	2147	O	N	-	0.5	14.7	CALM	VAR	NW	0.4	PT. CLOUDY
					3.0	14.5					
					6.0	14.0					
					9.0	13.8					
					11.0	13.8					
6-16-80	1410	P	D	BOTTOM	SURFACE	15.0	WNW	10-15	NW	0.3-0.6	CLEAR
					MID-DEPTH	15.0					
					BOTTOM	15.0					
6-16-80	2330	P	N	-	SURFACE	10.5	NE	0-5	NW	0-0.1	CLEAR
					MID-DEPTH	10.5					
					BOTTOM	10.5					
6-16-80	1510	Q	D	BOTTOM	SURFACE	14.5	WNW	10-15	WNW	0.3-0.6	CLEAR
					MID-DEPTH	14.5					
					BOTTOM	14.5					
6-17-80	0035	Q	N	-	SURFACE	11.0	NE	0-5	NW	0-0.1	CLEAR
					MID-DEPTH	11.0					
					BOTTOM	11.0					
6-16-80	1550	R	D	BOTTOM	SURFACE	15.5	WNW	10-15	WNW	0.3-0.6	CLEAR
					MID-DEPTH	15.5					
					BOTTOM	15.5					
6-17-80	0125	R	N	-	SURFACE	11.5	NE	0-5	NW	0-0.1	CLEAR
					MID-DEPTH	11.5					
					BOTTOM	11.5					
6-17-80	1117	W	D	2.75	0.5	13.0	WSW	0-5	WSW	0-0.3	CLEAR
					4.5	12.5					
					8.5	10.0					
					11.5	8.8					
					14.0	13.7					
6-18-80	2107	W	N	-	0.5	14.8	CALM	VAR	NW	0.4	PT. CLOUDY
					4.5	14.8					
					8.5	13.8					
					11.5	13.7					
					14.0	13.0					
7-01-80	1135	A	D	1.5	SURFACE	17.6	S	10-15	SW	0.5-1.0	CLOUDY
					MID-DEPTH	17.6					
					BOTTOM	17.6					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
7-01-80	0053	A	N	-	SURFACE	17.0	NE	0-5	CALM	0-0.1	CLEAR
					MID-DEPTH	16.3					
					BOTTOM	15.3					
7-01-80	1144	B	D	1.5	SURFACE	17.6	S	10-15	SW	0.6-1.0	CLOUDY
					MID-DEPTH	17.5					
					BOTTOM	17.4					
7-01-80	0028	B	N	-	SURFACE	17.0	NE	0-5	CALM	0-0.1	CLEAR
					MID-DEPTH	17.0					
					BOTTOM	15.3					
7-01-80	1644	C	D	2.5	0.5	19.8	SE	0-5	SE	0.3-0.6	OVERCAST
					2.0	19.8					
					4.0	19.8					
					5.5	19.8					
7-01-80	2243	C	N	-	0.5	21.0	VAR	0-5	S	0.3-0.6	OVERCAST
					2.0	21.0					
					4.0	20.9					
					5.5	20.9					
7-01-80	1609	D	D	4.75	0.5	19.5	SE	5-10	SE	0.3-0.6	OVERCAST
					2.5	19.5					
					4.5	19.5					
					6.5	19.4					
					8.5	19.4					
7-01-80	2209	D	N	-	0.5	20.8	VAR	0-5	S	0-0.3	OVERCAST
					2.5	20.8					
					4.5	20.8					
					6.5	20.7					
					8.5	20.7					
7-01-80	1540	F	D	4.5	0.5	19.3	S	5-10	S	0.3-0.6	OVERCAST
					3.0	19.3					
					6.0	19.3					
					9.0	19.2					
					11.0	19.2					
7-01-80	2142	E	N	-	0.5	20.8	N	5-10	S	0-0.3	OVERCAST
					3.0	20.7					
					6.0	20.6					
					9.0	20.6					
					11.0	20.6					
7-01-80	1503	F	D	4.5	0.5	19.5	S	5-10	S	0.3-0.6	OVERCAST
					4.5	19.5					
					8.5	19.5					
					11.5	19.4					
					14.0	18.0					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
7-01-80	2125	F	N	-	0.5	20.5	N	5-10	VAR	1.0-2.0	OVERCAST
					4.5	20.4					
					8.5	20.3					
					11.5	19.2					
					14.0	17.8					
7-01-80	1351	I	D	2.0	SURFACE	17.1	SE	5-10	S	0.6-0.9	OVERCAST
					MID-DEPTH	17.1					
					BOTTOM	17.1					
7-01-80	0213	I	N	-	SURFACE	17.7	NE	0-5	VAR	0-0.1	PT. CLOUDY
					MID-DEPTH	17.4					
					BOTTOM	16.4					
7-01-80	1337	J	D	2.7	SURFACE	16.6	SE	5-10	S	0.6-0.9	OVERCAST
					MID-DEPTH	16.6					
					BOTTOM	17.0					
7-01-80	0152	J	N	-	SURFACE	17.6	NE	0-5	VAR	0-0.1	PT. CLOUDY
					MID-DEPTH	17.2					
					BOTTOM	16.0					
7-01-80	1426	L	D	3.5	0.5	18.8	SW	5-10	SW	0.4	OVERCAST
					2.0	18.8					
					4.0	18.7					
					5.5	18.7					
7-01-80	0058	L	N	-	0.5	21.0					
					2.0	21.0					
					4.0	20.9					
					5.5	20.9					
7-01-80	1354	N	D	3.5	0.5	19.2	SW	10-15	SW	0.4-0.6	OVERCAST
					2.5	19.0					
					4.5	18.9					
					6.5	18.8					
					8.5	18.8					
7-01-80	0024	N	N	-	0.5	21.2	N	5-10	VAR	0-0.1	PT. CLOUDY
					2.5	21.1					
					4.5	21.0					
					6.5	20.8					
					8.5	20.7					
7-01-80	1327	O	D	3.75	0.5	19.3	SW	10-15	SW	0.4-0.6	OVERCAST
					3.0	19.1					
					6.0	18.8					
					9.0	18.3					
					11.0	18.2					
7-01-80	2354	O	N	-	0.5	21.1	N	5-10	VAR	0-0.1	OVERCAST
					3.0	20.7					
					6.0	20.5					
					9.0	20.4					
					11.0	20.4					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
7-01-80	1530	P	D		SURFACE	18.6	SW	5-10	SW	0.6	OVERCAST
					MID-DEPTH	18.6					
					BOTTOM	18.6					
7-01-80	0100	P	N	-	SURFACE	17.3	VAR	0-5	SE	0.1	CLEAR
					MID-DEPTH	16.9					
					BOTTOM	16.5					
7-01-80	1545	Q	D		SURFACE	18.4	SW	5-10	SW	0.6	OVERCAST
					MID-DEPTH	18.4					
					BOTTOM	18.4					
7-01-80	0140	Q	N	-	SURFACE	17.3	VAR	0-5	SE	0.1	CLEAR
					MID-DEPTH	17.1					
					BOTTOM	17.0					
7-01-80	1525	R	D		SURFACE	18.7	SW	5-10	SW	0.6	OVERCAST
					MID-DEPTH	18.7					
					BOTTOM	18.7					
7-01-80	0155	R	N	-	SURFACE	16.9	VAR	0-5	SE	0.1	CLEAR
					MID-DEPTH	16.7					
					BOTTOM	16.1					
7-01-80	1252	W	D	3.75	0.5	20.5	SW	10-15	SW	0.4-0.6	OVERCAST
					4.5	20.4					
					8.5	19.2					
					11.5	18.5					
					14.0	17.2					
7-01-80	2320	W	N	-	0.5	21.2	N	10	VAR	0.1	OVERCAST
					4.5	20.6					
					8.5	20.2					
					11.5	17.7					
					14.0	17.5					
7-15-80	1718	A	D	1.3	SURFACE	22.8	SW	10-15	SW	0.3-1.0	PT. CLOUDY
					MID-DEPTH	22.7					
					BOTTOM	22.6					
7-15-80	2112	A	N	-	SURFACE	23.0	SW	15-20	SW	0.3-0.6	CLEAR
					MID-DEPTH	23.0					
					BOTTOM	23.0					
7-15-80	1700	R	D	1.4	SURFACE	22.8	SW	10-15	SW	0.3-1.0	PT. CLOUDY
					MID-DEPTH	22.0					
					BOTTOM	22.0					
7-15-80	2121	P	N	-	SURFACE	22.8	SW	15-20	SW	0.3-0.6	CLEAR
					MID-DEPTH	22.8					
					BOTTOM	22.8					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
7-14-80	1759	C	D	3.6	0.5	23.0	S	5-10	S	0-0.1	OVERCAST
					2.0	22.9					
					4.0	22.9					
					5.5	22.9					
7-14-80	2238	C	N	-	0.5	25.8	SSE	15-20	S	0.6-1.0	PT. CLOUDY
					2.0	25.8					
					4.0	25.6					
					5.5	25.5					
7-14-80	1725	D	D	3.9	0.5	22.9	S	5-10	S	0-0.1	OVERCAST
					2.5	22.5					
					4.5	22.5					
					6.5	22.4					
					8.5	22.4					
7-14-80	2203	D	N	-	0.5	25.2	SE	15-20	S	0.6	PT. CLOUDY
					2.5	25.2					
					4.5	25.0					
					6.5	24.5					
					8.5	23.5					
7-14-80	1653	E	D	3.9	0.5	22.8	S	5-10	S	0.6	PT. CLOUDY
					3.0	22.4					
					6.0	22.3					
					9.0	22.1					
					11.0	22.1					
7-14-80	2131	F	N	-	0.5	25.6	S	10-15	S	0.6	PT. CLOUDY
					3.0	25.5					
					6.0	25.2					
					9.0	22.3					
					11.0	22.1					
7-14-80	1538	F	D	5.0	0.5	22.5	S	5-10	S	0.6	PT. CLOUDY
					4.5	22.3					
					8.5	21.6					
					11.5	20.1					
					14.0	15.5					
7-14-80	2113	F	N	-	0.5	25.2	S	10-15	S	0.6	PT. CLOUDY
					4.5	25.0					
					8.5	22.3					
					11.5	20.8					
					14.0	17.5					
7-17-80	1717	I	D	1.25	SURFACE	22.3	W	0-5	WSW	1.0	CLEAR
					MID-DEPTH	22.3					
					BOTTOM	22.0					
7-15-80	2127	I	N	-	SURFACE	22.5	N	0-5	SW	0-0.1	CLEAR
					MID-DEPTH	22.5					
					BOTTOM	22.5					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
7-15-80	1657	J	D	2.5	SURFACE	22.5	W	0-5	WSW	1.0	PT. CLOUDY
					MID-DEPTH	22.0					
					BOTTOM	22.0					
7-15-80	2118	J	N	-	SURFACE	22.3	N	0-5	SW	0-0.1	CLEAR
					MID-DEPTH	21.5					
					BOTTOM	21.5					
7-14-80	1501	L	D	4.0	0.5	22.4	S	10-15	SSW	0-0.1	PT. CLOUDY
					2.0	22.4					
					4.0	22.3					
					5.5	22.3					
7-15-80	0054	L	N	-	0.5	25.1	S	15-20	S	0.6-1.0	CLEAR
					2.0	25.1					
					4.0	25.1					
					5.5	25.1					
7-14-80	1423	N	D	3.5	0.5	22.5	S	10-15	SSW	0-0.1	SUNNY
					2.5	22.4					
					4.5	22.0					
					6.5	21.9					
					8.5	21.8					
7-15-80	0019	N	N	-	0.5	25.0	S	15-20	S	0.6-1.0	PT. CLOUDY
					2.5	25.0					
					4.5	25.0					
					6.5	24.9					
					8.5	24.9					
7-14-80	1347	O	D	4.0	0.5	22.5	SE	5-10	SW	0.6-1.0	PT. CLOUDY
					3.0	22.0					
					6.0	21.5					
					9.0	21.5					
					11.0	21.1					
7-14-80	2347	O	N	-	0.5	25.3	SSE	15-20	S	0.5-1.0	CLEAR
					3.0	25.3					
					6.0	24.8					
					9.0	23.9					
					11.0	23.5					
7-14-80	1425	P	D	BOTTOM	SURFACE	22.4	SW	10-15	SW	0.3-1.0	PT. CLOUDY
					MID-DEPTH	22.4					
					BOTTOM	22.4					
7-14-80	2245	P	N	-	SURFACE	22.6	SW	15-20	SW	0.6	CLEAR
					MID-DEPTH	22.6					
					BOTTOM	22.6					
7-14-80	1515	Q	D	BOTTOM	SURFACE	22.2	SW	15-20	SW	0.3-0.6	PT. CLOUDY
					MID-DEPTH	22.2					
					BOTTOM	22.2					
7-14-80	2335	Q	N	-	SURFACE	21.4	SW	20-15	SW	0.6	CLEAR
					MID-DEPTH	21.4					
					BOTTOM	21.4					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
7-14-80	1555	R	D	BOTTOM	SURFACE	22.6	SW	15-20	SW	0.3-0.6	PT. CLOUDY
					MID-DEPTH	22.6					
					BOTTOM	22.6					
7-14-80	0020	R	N	-	SURFACE	21.6	SW	20-25	SW	0.6	CLEAR
					MID-DEPTH	21.6					
					BOTTOM	21.6					
7-14-80	1309	W	D	4.0	0.5	21.3	SW	10	SW	0.6-1.0	PT. CLOUDY
					4.5	21.2					
					8.5	21.1					
					11.5	21.1					
					14.0	21.0					
7-14-80	2308	W	N	-	0.5	25.1	SE	15-20	S	0.6-1.0	CLEAR
					4.5	25.1					
					8.5	24.3					
					11.5	22.0					
					14.0	20.0					
8-04-80	1853	A	D	BOTTOM	SURFACE	23.7	S	5-10	S	0.3-0.6	CLEAR
					MID-DEPTH	23.7					
					BOTTOM	23.5					
8-04-80	2356	A	N	-	SURFACE	22.7	SW	5-10	SW	0.3-0.6	PT. CLOUDY
					MID-DEPTH	22.7					
					BOTTOM	22.5					
8-04-80	1820	B	D	BOTTOM	SURFACE	24.0	S	5-10	S	0.3-0.6	CLEAR
					MID-DEPTH	24.0					
					BOTTOM	23.9					
8-04-80	2324	B	N	-	SURFACE	22.5	SW	5-10	SW	0.3-0.6	PT. CLOUDY
					MID-DEPTH	22.5					
					BOTTOM	22.5					
8-05-80	1854	C	D	3.0	0.5	24.3	S	5-10	SW	0.6-1.0	CLEAR
					2.0	24.3					
					4.0	24.3					
					5.5	24.3					
8-05-80	2241	C	N	-	0.5	22.2	S	5-10	SW	0.6-1.0	CLEAR
					2.0	22.2					
					4.0	22.2					
					5.5	22.2					
8-05-80	1817	D	D	5.5	0.5	24.0	S	5-10	SW	0.6-1.0	CLEAR
					2.5	23.9					
					4.5	23.9					
					6.5	23.9					
					8.5	23.7					
8-05-80	2203	D	N	-	0.5	22.3	S	5-10	SW	0.6-1.0	CLEAR
					2.5	22.3					
					4.5	22.3					
					6.5	22.3					
					8.5	22.3					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND		WAVES		WEATHER
							DIR. FROM	SPEED (MPH)	DIR. FROM	HT. (M)	
8-05-80	1743	E	D	7.0	0.5	23.1	SW	5-10	SW	0.6-1.0	CLEAR
					3.0	23.0					
					6.0	22.8					
					9.0	22.7					
					11.0	22.7					
8-05-80	2131	F	N	-	0.5	23.0	S	5-10	SW	0.6-1.0	CLEAR
					3.0	23.0					
					6.0	23.0					
					9.0	22.9					
					11.0	22.8					
8-05-80	1620	F	D	8.0	0.5	23.2	W	5-10	SW	0.6-1.0	CLEAR
					4.5	23.1					
					8.5	22.9					
					11.5	22.8					
					14.0	22.8					
8-05-80	2048	F	N	-	0.5	22.5	S	5-10	SW	0.6-1.0	CLEAR
					4.5	22.4					
					11.5	21.9					
					14.0	21.3					
8-04-80	1806	I	D	BOTTOM	SURFACE	22.0	S	10-15	SE	0-0.3	CLEAR
					MID-DEPTH	22.0					
					BOTTOM	22.0					
8-04-80	2313	I	N	-	SURFACE	24.4	SW	10-15	SW	0-0.1	PT. CLOUDY
					MID-DEPTH	24.4					
					BOTTOM	24.4					
8-04-80	1743	J	D	4.0	SURFACE	22.0	SE	10-15	SE	0-0.3	CLEAR
					MID-DEPTH	22.0					
					BOTTOM	22.5					
8-04-80	2303	J	N	-	SURFACE	23.3	SW	10-15	SW	0-0.1	PT. CLOUDY
					MID-DEPTH	23.3					
					BOTTOM	23.3					
8-05-80	1535	L	D	3.1	0.5	23.0	SW	5-10	SW	0.6	CLEAR
					2.0	23.0					
					4.0	22.9					
					5.5	22.9					
8-06-80	0113	L	N	-	0.5	22.0	SW	5-10	SW	0.6	CLEAR
					2.0	22.0					
					4.0	22.0					
					5.5	21.9					
8-05-80	1458	N	D	4.2	0.5	23.0	SW	5-10	SW	0.3-0.6	CLEAR
					2.5	22.9					
					4.5	22.7					
					6.5	22.5					
					8.5	22.5					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
8-06-80	0033	N	N	-	0.5	22.2	SW	5-10	SW	0.6	CLEAR
					2.5	22.2					
					4.5	22.2					
					6.5	22.2					
					8.5	22.1					
8-05-80	1420	O	D	5.0	0.5	23.5	SW	5-10	SW	0.3-0.6	CLEAR
					3.0	23.3					
					6.0	23.2					
					9.0	23.1					
					11.0	22.9					
8-06-80	2358	O	N	-	0.5	22.5	SW	5-10	SW	0.3-0.6	CLEAR
					3.0	22.3					
					6.0	22.1					
					9.0	21.9					
					11.0	21.9					
8-05-80	1500	P	D	BOTTOM	SURFACE	23.6	S	5-10	S	0.3-0.6	CLEAR
					MID-DEPTH	23.6					
					BOTTOM	23.6					
8-04-80	2200	P	N	-	SURFACE	24.5	SW	10-15	SW	0.3-0.6	PT. CLOUDY
					MID-DEPTH	24.5					
					BOTTOM	24.5					
8-05-80	1520	Q	D	BOTTOM	SURFACE	24.0	SW	5-10	SW	0.6-0.9	CLEAR
					MID-DEPTH	24.0					
					BOTTOM	24.0					
8-04-80	2230	Q	N	-	SURFACE	23.7	SW	10-15	SW	0.3-0.6	PT. CLOUDY
					MID-DEPTH	23.7					
					BOTTOM	23.7					
8-05-80	1520	R	D	BOTTOM	SURFACE	24.5	SW	5-10	SW	0.6-0.9	CLEAR
					MID-DEPTH	24.5					
					BOTTOM	24.5					
8-04-80	2245	R	N	-	SURFACE	24.5	SW	10-15	SW	0.3-0.6	PT. CLOUDY
					MID-DEPTH	24.5					
					BOTTOM	24.5					
8-04-80	1343	W	D	7.0	0.5	23.5	SW	5-10	SW	0.3-1.0	PT. CLOUDY
					4.5	23.5					
					8.5	23.5					
					11.5	23.3					
					14.0	23.2					
8-05-80	2316	W	N	-	0.5	22.0	S	5-10	SW	0.6-1.0	CLEAR
					4.5	22.0					
					8.5	21.9					
					11.5	21.9					
					14.0	21.3					
8-18-80	1350	A	D	BOTTOM	SURFACE	20.5	SW	0-5	W	0.3-1.0	CLEAR
					MID-DEPTH	20.5					
					BOTTOM	19.5					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
8-18-80	2152	A	N	-	SURFACE	21.2	SW	0-5	SW	0-0.3	CLEAR
					MID-DEPTH	21.0					
					BOTTOM	21.0					
8-18-80	1400	B	D	2.5	SURFACE	20.1	SW	0-5	W	0.3-1.0	CLEAR
					MID-DEPTH	19.8					
					BOTTOM	18.9					
8-18-80	2130	B	N	-	SURFACE	20.5	SW	0-5	SW	0-0.3	CLEAR
					MID-DEPTH	19.5					
					BOTTOM	17.2					
8-18-80	1731	C	D	5.5	0.5	20.0	SSW	0-5	SWW.	0.3	CLEAR
					2.0	18.0					
					4.0	15.2					
					5.5	13.6					
8-18-80	2151	C	N	-	0.5	19.0	S	0-5	CALM	0-0.1	CLEAR
					2.0	19.0					
					4.0	18.4					
					5.5	17.0					
8-18-80	1657	D	D	5.0	0.5	20.0	SSW	0-5	SSW	0.3	CLEAR
					2.5	19.0					
					4.5	16.4					
					6.5	14.9					
					8.5	10.8					
8-18-80	2114	D	N	-	0.5	19.5	S	0-5	CALM	0-0.1	CLEAR
					2.5	19.0					
					4.5	18.1					
					6.5	16.6					
					8.5	15.8					
8-18-80	1624	F	D	4.5	0.5	20.1	SW	5-10	W	0.3-0.6	CLEAR
					3.0	19.6					
					6.0	16.0					
					9.0	10.0					
					11.0	8.5					
8-18-80	2044	F	N	-	0.5	19.3	S	5-10	SSW	0.3	CLEAR
					3.0	18.3					
					6.0	16.8					
					9.0	9.7					
					11.0	8.3					
8-18-80	1543	F	D	4.5	0.5	20.7	SW	5-10	SW	0.3-0.6	CLEAR
					4.5	19.3					
					8.5	15.3					
					11.5	9.7					
					14.0	7.0					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
8-18-80	2021	F	N	-	0.5	19.3	S	5-10	SSW	0.3	CLEAR
					4.5	18.5					
					8.5	14.9					
					11.5	9.8					
					14.0	9.1					
8-18-80	1548	I	D	BOTTOM	SURFACE	19.3	W	5-10	WNW	0.3-0.6	CLEAR
					MID-DEPTH	19.3					
					BOTTOM	19.3					
8-18-80	2140	I	N	-	SURFACE	20.0	SW	5-10	WSW	0-0.3	CLEAR
					MID-DEPTH	18.5					
					BOTTOM	18.5					
8-18-80	1539	J	D	BOTTOM	SURFACE	19.5	W	5-10	WNW	0.3-0.6	CLEAR
					MID-DEPTH	18.9					
					BOTTOM	18.6					
8-18-80	2122	J	N	-	SURFACE	20.5	SW	5-10	WSW	0-0.3	CLEAR
					MID-DEPTH	17.0					
					BOTTOM	17.0					
8-18-80	1508	L	D	4.0	0.5	20.0	W	5-10	W	0.3-0.6	CLEAR
					2.0	19.8					
					4.0	19.1					
					5.5	18.4					
8-18-80	0015	L	N	-	0.5	19.0	SE	5-10	S	0-0.1	CLEAR
					2.0	19.0					
					4.0	17.0					
					5.5	16.0					
8-18-80	1441	N	D	5.0	0.5	20.0	W	5-10	SW	0.3-0.6	CLEAR
					2.5	19.9					
					4.5	19.3					
					6.5	18.2					
					8.5	17.7					
8-18-80	2337	N	N	-	0.5	19.0	SE	5-10	S	0-0.3	CLEAR
					2.5	18.9					
					4.5	17.8					
					6.5	15.5					
					8.5	13.5					
8-18-80	1357	O	D	3.5	0.5	20.8	W	5-10	SW	0.3-0.6	CLEAR
					3.0	20.5					
					6.0	19.9					
					9.0	18.5					
					11.0	18.1					
8-18-80	2304	O	N	-	0.5	19.0	SSE	5-10	S	0-0.3	CLEAR
					3.0	18.9					
					6.0	18.0					
					9.0	16.4					
					11.0	12.5					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
8-19-80	1325	P	D	BOTTOM	SURFACE	20.2	SW	0-5	SW	0.3-0.6	CLEAR
					MID-DEPTH	20.2					
					BOTTOM	20.2					
8-20-80	2025	P	N	-	SURFACE	21.9	VAR	0-5	W	0.0	CLEAR
					MID-DEPTH	21.9					
					BOTTOM	21.9					
8-19-80	1410	Q	D	BOTTOM	SURFACE	21.0	SW	0-5	SW	0.3-0.6	CLEAR
					MID-DEPTH	21.0					
					BOTTOM	21.0					
8-20-80	2100	Q	N	-	SURFACE	22.5	VAR	0-5	W	0-0.3	CLEAR
					MID-DEPTH	22.5					
					BOTTOM	22.5					
8-19-80	1448	R	D	BOTTOM	SURFACE	21.3	SW	0-5	SW	0.3-0.6	CLEAR
					MID-DEPTH	21.3					
					BOTTOM	21.3					
8-20-80	2120	R	N	-	SURFACE	22.7	VAR	0-5	W	0-0.3	CLEAR
					MID-DEPTH	22.7					
					BOTTOM	22.7					
8-18-80	1313	W	D	4.0	0.5	20.9	W	5-10	SW	0.3-0.6	CLEAR
					4.5	20.1					
					8.5	18.9					
					11.5	17.1					
					14.0	11.8					
8-18-80	2224	W	N	-	0.5	20.0	S	5-10	SSW	0-0.3	CLEAR
					4.5	19.3					
					8.5	17.3					
					11.5	12.0					
					14.0	7.8					
9-15-80	1531	A	D	1.5	SURFACE	16.9	E	5-10	SE	0-0.3	OVERCAST
					MID-DEPTH	16.8					
					BOTTOM	16.6					
9-15-80	2236	A	N	-	SURFACE	18.0	S	5-10	S	0.3	OVERCAST
					MID-DEPTH	18.0					
					BOTTOM	18.0					
9-15-80	1512	B	D	2.75	SURFACE	16.7	E	5-10	SE	0-0.3	OVERCAST
					MID-DEPTH	16.4					
					BOTTOM	14.7					
9-15-80	2250	B	N	-	SURFACE	18.5	S	5-10	S	0.3	OVERCAST
					MID-DEPTH	17.5					
					BOTTOM	17.5					
9-15-80	1746	C	D	3.0	0.5	16.9	SE	5-10	SSE	0.3	OVERCAST
					2.0	16.9					
					4.0	16.2					
					5.5	15.4					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
9-15-80	1938	C	N	-	0.5	17.0	SE	10-15	SE	0-0.3	OVERCAST
					2.0	17.0					
					4.0	16.0					
					5.5	13.4					
9-15-80	1712	D	D	3.0	0.5	17.0	SE	5-10	SE	0.3	OVERCAST
					2.5	16.8					
					4.5	15.0					
					6.5	11.0					
					8.5	8.8					
9-15-80	2009	D	N	-	0.5	18.5	SE	10-15	SE	0.3	OVERCAST
					2.5	18.5					
					4.5	18.2					
					6.5	16.5					
					8.5	10.5					
9-15-80	1642	F	D	3.0	0.5	17.0	SE	0-5	S	0.3	OVERCAST
					3.0	17.0					
					6.0	12.4					
					9.0	8.5					
					11.0	7.8					
9-15-80	2040	F	N	-	0.5	17.3	SE	10-15	S	0.3	OVERCAST
					3.0	17.3					
					6.0	17.2					
					9.0	10.0					
					11.0	8.1					
9-15-80	1607	F	D	3.2	0.5	18.0	SE	0-5	S	0.3	OVERCAST
					4.5	17.8					
					8.5	10.1					
					11.5	8.1					
					14.0	17.5					
9-15-80	2117	F	N	-	0.5	17.2	SE	10-15	S	0.3	OVERCAST
					4.5	17.2					
					8.5	16.6					
					11.5	7.4					
					14.0	6.8					
9-15-80	1537	I	D	1.0	SURFACE	19.0	ESE	0-5	S	0-0.1	OVERCAST
					MID-DEPTH	19.0					
					BOTTOM	19.0					
9-15-80	2305	I	N	-	SURFACE	16.5	SE	10-15	SW	0.3-0.6	OVERCAST
					MID-DEPTH	16.0					
					BOTTOM	16.0					
9-15-80	1516	J	D	2.0	SURFACE	18.0	ESE	0-5	S	0-0.1	OVERCAST
					MID-DEPTH	17.5					
					BOTTOM	17.0					
9-15-80	2244	J	N	-	SURFACE	16.4	SE	10-15	SW	0.3-0.6	OVERCAST
					MID-DEPTH	16.4					
					BOTTOM	14.5					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
9-15-80	1532	L	D	2.7	0.5	16.9	SE	5-10	SE	0.3	OVERCAST
					2.0	16.8					
					4.0	14.5					
					5.5	13.7					
9-15-80	2356	L	N	-	0.5	19.2	SE	15-20	S	0.6-1.0	OVERCAST
					2.0	19.2					
					4.0	18.8					
					5.5	18.2					
9-15-80	1458	N	D	2.7	0.5	18.0	SE	5-10	SE	0.3	OVERCAST
					2.5	17.5					
					4.5	15.9					
					6.5	13.3					
					8.5	12.8					
9-15-80	2321	N	N	-	0.5	19.8	SE	10-15	SSE	0.6	OVERCAST
					2.5	19.8					
					4.5	19.7					
					6.5	19.0					
					8.5	18.3					
9-15-80	1427	O	D	3.8	0.5	18.0	SE	5-10	SE	0.3	OVERCAST
					3.0	17.4					
					6.0	14.7					
					9.0	11.2					
					11.0	11.0					
9-15-80	2248	O	N	-	0.5	18.1	SE	10-15	SSE	0.3-0.6	OVERCAST
					3.0	18.1					
					6.0	18.1					
					9.0	17.3					
					11.0	15.2					
9-18-80	1515	P	D	BOTTOM	SURFACE	12.7	WSW	20-25	WSW	0-0.3	CLEAR
					MID-DEPTH	12.7					
					BOTTOM	12.7					
9-15-80	2040	P	N	-	SURFACE	18.2	S	0-5	SW	0-0.3	OVERCAST
					MID-DEPTH	18.2					
					BOTTOM	18.2					
9-18-80	1610	Q	D	BOTTOM	SURFACE	12.7	WSW	20-25	WSW	0-0.3	CLEAR
					MID-DEPTH	12.7					
					BOTTOM	12.7					
9-15-80	2000	Q	N	-	SURFACE	16.3	SE	0-5	VAR	0-0.1	OVERCAST
					MID-DEPTH	16.3					
					BOTTOM	16.3					
9-18-80	1545	R	D	BOTTOM	SURFACE	12.7	WSW	20-25	WSW	0-0.3	CLEAR
					MID-DEPTH	12.7					
					BOTTOM	12.7					

Appendix 5. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	DEPTH (M)	TEMPERATURE C	WIND DIR. FROM	WIND SPEED (MPH)	WAVES DIR. FROM	WAVES HT. (M)	WEATHER
9-15-80	1940	P	N	-	SURFACE	16.5	SE	0-5	VAR	0-0.1	OVERCAST
					MID-DEPTH	16.5					
					BOTTOM	16.5					
9-15-80	1346	W	D	4.0	0.5	20.0	SE	5-10	SE	0.3	OVERCAST
					4.5	19.7					
					8.5	14.7					
					11.5	9.7					
					14.0	9.2					
9-15-80	2208	W	N	-	0.5	18.1	SE	10-15	SE	0.3-0.6	OVERCAST
					4.5	18.0					
					8.5	18.0					
					11.0	13.5					
					14.0	9.0					

Appendix 6. Meteorological and limnological parameters measured during fish larvae sampling by sled, April to September 1980 near the J. H. Campbell Plant, eastern Lake Michigan.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	TEMPERATURE C SURFACE	MID DEPTH	BOTTOM	WIND DIR. FROM	SPEED (MPH)	WAVES DIR. FROM	HT. (M)	WEATHER
4-21-80	1606	A	D	2.0	7.0	7.0	7.0	SSE	0-5	S	0-0.1	HAZE
4-21-80	2305	A	N	-	7.5	7.5	7.5	SSW	5-10	S	0.3	CLEAR
4-21-80	1548	B	D	2.0	6.9	6.9	6.9	SSE	0-5	S	0-0.1	HAZE
4-21-80	2245	B	N	-	6.7	6.7	6.7	SSW	5-10	S	0.3	CLEAR
4-21-80	1539	C	D	2.0	6.5	5.6	5.6	SSE	0-5	S	0-0.1	HAZE
4-21-80	2035	C	N	-	6.0	6.0	6.0	SSW	5-10	S	0.3	CLEAR
4-21-80	1529	D	D	2.0	5.8	5.4	5.0	SSE	0-5	S	0-0.1	HAZE
4-21-80	2225	D	N	-	5.2	5.2	5.2	SSW	5-10	S	0.3	CLEAR
4-21-80	1518	E	D	2.0	6.0	4.9	4.8	SSE	0-5	S	0-0.1	HAZE
4-21-80	2215	E	N	-	4.5	4.5	4.5	SSW	5-10	S	0.3	CLEAR
4-21-80	1507	F	D	2.5	5.1	4.6	4.6	SSE	0-5	S	0-0.1	HAZE
4-21-80	2205	F	N	-	4.0	4.0	4.0	SSW	5-10	S	0.3	CLEAR
4-21-80	1528	I	D	BOTTOM	7.7	7.5	7.0	SSE	0-5	CALM	CALM	HAZE
4-21-80	2333	I	N	-	6.7	6.7	6.7	S	10-15	CALM	CALM	CLEAR
4-21-80	1534	J	D	2.0	6.6	6.4	5.8	SSE	0-5	CALM	CALM	HAZE
4-21-80	2317	J	N	-	6.5	6.5	6.5	S	10-15	CALM	CALM	CLEAR
4-21-80	1546	L	D	2.0	5.6	5.5	5.1	SSE	0-5	CALM	CALM	HAZE
4-21-80	2303	L	N	-	5.2	5.2	5.5	S	10-15	CALM	CALM	CLEAR
4-21-80	1556	N	D	2.0	5.5	5.2	4.5	SSE	0-5	CALM	CALM	HAZE
4-21-80	2251	N	N	-	5.0	4.5	4.5	S	10-15	CALM	CALM	CLEAR
4-21-80	1607	O	D	2.5	5.3	4.2	4.2	SSE	0-5	CALM	CALM	HAZE
4-21-80	2241	O	N	-	4.5	4.5	4.5	S	10-15	CALM	CALM	CLEAR
4-21-80	1613	P	D	2.0	8.5	8.5	8.5	SSE	0-5	S	0-0.1	HAZE
4-21-80	2315	P	N	-	7.6	7.6	7.6	SSW	5-10	S	0.3	CLEAR
4-21-80	1459	Q	D	BOTTOM	7.5	7.5	7.7	SSE	0-5	CALM	CALM	HAZE
4-21-80	2210	Q	N	-	6.5	6.5	6.5	S	10-15	CALM	CALM	CLEAR
4-21-80	1512	R	D	BOTTOM	9.0	9.0	9.0	SSW	0-5	CALM	CALM	HAZE
4-21-80	2348	R	N	-	6.5	6.5	6.5	S	10-15	CALM	CALM	CLEAR
4-21-80	1616	W	D	3.0	3.5	3.5	3.5	SSE	0-5	CALM	CALM	HAZE
4-21-80	2228	W	N	-	4.5	4.5	4.5	S	10-15	CALM	CALM	CLEAR
5-19-80	1556	A	D	BOTTOM	10.0	10.0	10.0	VAR	0-5	NW	0-0.3	HAZE
5-19-80	2324	A	N	-	9.3	8.2	8.2	E	0-5	N	0.3	PT. CLOUDY
5-19-80	1540	B	D	2.0	9.6	9.6	9.6	VAR	0-5	NW	0-0.3	HAZE
5-19-80	2306	B	N	-	8.3	7.2	7.2	NE	0-5	N	0.3	PT. CLOUDY
5-19-80	1530	C	D	3.0	9.2	8.8	7.8	VAR	0-5	NW	0-0.3	HAZE
5-19-80	2250	C	N	-	8.2	6.9	6.9	NE	0-5	N	0.3	PT. CLOUDY
5-19-80	1520	D	D	2.8	9.3	8.3	7.5	VAR	0-5	NW	0-0.3	HAZE
5-19-80	2237	D	N	-	8.2	7.6	6.1	N	0-5	N	0.3	PT. CLOUDY
5-19-80	1509	E	D	4.0	9.2	7.8	6.4	VAR	0-5	NW	0-0.3	HAZE
5-19-80	2224	E	N	-	8.5	8.4	5.5	N	0-5	N	0.3	PT. CLOUDY
5-19-80	1456	F	D	4.5	9.2	6.3	5.5	VAR	0-5	NW	0-0.3	HAZE
5-19-80	2206	F	N	-	8.6	6.6	5.2	N	0-5	N	0.3	PT. CLOUDY
5-19-80	1606	I	D	BOTTOM	11.0	10.7	10.0	N	5-10	NW	0-0.3	LT. FOG
5-19-80	2259	I	N	-	9.6	9.6	9.6	NE	5-10	N	0.3	CLEAR
5-19-80	1545	J	D	2.5	9.0	9.0	8.5	N	5-10	NW	0-0.3	LT. FOG

Appendix 6. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	TEMPERATURE C SURFACE	MID DEPTH	BOTTOM	WIND DIR. FROM	SPEED (MPH)	WAVES DIR. FROM	HT. (M)	WEATHER
5-19-80	2238	J	N	-	9.2	8.6	8.6	NE	5-10	N	0.3	CLEAR
5-19-80	1534	L	D	3.0	9.3	7.5	7.5	N	5-10	NW	0-0.3	LT. FOG
5-19-80	2227	L	N	-	8.7	8.5	7.3	N	5-10	N	0.3	CLEAR
5-19-80	1522	N	D	3.0	9.1	8.7	5.5	N	5-10	NW	0-0.3	LT. FOG
5-19-80	2214	N	N	-	9.0	6.1	6.1	N	5-10	N	0.3	CLEAR
5-19-80	1510	O	D	3.0	9.1	8.2	5.3	N	5-10	NW	0-0.3	LT. FOG
5-19-80	2155	O	N	-	9.3	8.2	6.0	N	5-10	N	0.3	CLEAR
5-19-80	1606	P	D	BOTTOM	11.4	11.4	11.4	VAR	0-5	NW	0-0.3	HAZE
5-19-80	2334	P	N	-	9.6	9.2	9.1	E	0-5	N	0.3	PT. CLOUDY
5-19-80	1630	Q	D	BOTTOM	10.9	10.9	10.9	N	5-10	NW	0.3-0.6	LT. FOG
5-19-80	2321	Q	N	-	9.5	9.5	9.5	E	5-10	N	0-0.3	CLEAR
5-19-80	1622	R	D	BOTTOM	10.9	10.9	10.9	N	5-10	NW	0.3-0.6	LT. FOG
5-19-80	2310	R	N	-	9.6	9.6	9.6	E	5-10	N	0-0.3	CLEAR
5-19-80	1457	W	D	3.5	8.7	8.0	5.5	N	5-10	NW	0-0.3	LT. FOG
5-19-80	2141	W	N	-	9.0	7.3	5.7	N	5-10	N	0.3	CLEAR
6-02-80	1704	A	D	BOTTOM	15.7	15.4	15.2	NW	0-5	NW	0-0.3	PT. CLOUDY
6-03-80	2344	A	N	-	15.5	15.5	13.3	NE	0-5	N	0-0.3	CLEAR
6-02-80	1640	B	D	2.7	15.5	15.0	14.9	N	0-5	W	0-0.3	PT. CLOUDY
6-03-80	2318	B	N	-	15.0	12.3	10.5	NE	0-5	N	0-0.3	CLEAR
6-02-80	1628	C	D	3.2	15.5	14.5	14.2	N	0-5	N	0-0.3	PT. CLOUDY
6-03-80	2300	C	N	-	14.4	8.6	8.6	NE	0-5	N	0-0.3	CLEAR
6-02-80	1617	D	D	3.7	15.0	14.2	14.0	N	0-5	SW	0-0.3	PT. CLOUDY
6-03-80	2242	D	N	-	13.8	7.3	7.3	NE	0-5	N	0-0.3	CLEAR
6-02-80	1604	E	D	3.5	15.0	14.5	14.0	N	0-5	SW	0-0.3	PT. CLOUDY
6-03-80	2225	E	D	-	14.2	6.7	6.7	NE	0-5	N	0-0.3	CLEAR
6-02-80	1551	F	D	4.0	15.0	14.2	13.5	N	0-5	SW	0-0.3	PT. CLOUDY
6-03-80	2210	F	N	-	14.0	6.5	6.5	NE	0-5	N	0-0.3	CLEAR
6-04-80	1158	I	D	2.0	11.2	8.5	8.5	N	0-5	CALM	CALM	PT. CLOUDY
6-03-80	2327	I	N	-	14.0	14.0	14.0	NE	0-5	N	0-0.3	CLEAR
6-04-80	1135	J	D	2.25	11.0	7.5	7.5	N	0-5	CALM	CALM	PT. CLOUDY
6-03-80	2301	J	N	-	15.0	14.0	9.9	NE	0-5	N	0-0.3	CLEAR
6-04-80	1121	L	D	3.0	12.2	7.3	7.3	N	0-5	CALM	CALM	PT. CLOUDY
6-03-80	2248	L	N	-	14.0	8.5	7.5	NE	0-5	N	0-0.3	CLEAR
6-04-80	1108	N	D	3.2	14.0	7.5	6.5	N	0-5	CALM	CALM	PT. CLOUDY
6-03-80	2137	N	N	-	13.8	7.2	7.2	NE	0-5	N	0-0.3	CLEAR
6-04-80	1031	O	D	3.0	14.8	6.5	6.3	N	0-5	CALM	CALM	PT. CLOUDY
6-03-80	2125	O	N	-	13.8	7.0	7.0	NE	0-5	N	0-0.3	CLEAR
6-02-80	1725	P	D	BOTTOM	16.8	16.8	16.5	NW	0-5	NW	0-0.3	PT. CLOUDY
6-04-80	0023	P	N	-	13.8	11.5	11.5	NE	0-5	N	0-0.3	CLEAR
6-03-80	1045	Q	D	BOTTOM	15.8	15.8	15.7	NW	10-15	NW	1-1.3	CLEAR
6-04-80	0028	Q	N	-	15.0	13.5	13.5	NE	0-5	N	0-0.3	CLEAR
6-03-80	1100	R	D	BOTTOM	16.7	16.7	16.7	NW	10-15	NW	1-1.3	CLEAR
6-03-80	2351	R	N	-	15.7	14.0	14.0	NE	0-5	N	0-0.3	CLEAR
6-04-80	1071	W	D	3.5	13.6	6.3	6.1	N	0-5	CALM	CALM	PT. CLOUDY
6-03-80	2111	W	N	-	13.5	11.0	6.3	NE	0-5	N	0-0.3	CLEAR

Appendix 6. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	TEMPERATURE C SURFACE	MID DEPTH	BOTTOM	WIND DIR. FROM	SPEED (MPH)	WAVES DIR. FROM	HT. (M)	WEATHER
6-16-80	1445	A	D	.75	13.0	13.0	13.0	NW	15-20	NW	0.6-1.0	CLEAR
6-17-80	0018	A	N	-	10.5	10.5	10.5	VAR	10-15	VAR	0-0.3	CLEAR
6-16-80	1422	B	D	2.0	10.7	10.5	10.5	NW	15-20	NW	0.6-1.0	CLEAR
6-16-80	2357	B	N	-	11.0	10.5	9.5	VAR	10-15	VAR	0-0.3	CLEAR
6-16-80	1410	C	D	2.0	9.0	9.0	10.0	NW	15-20	NW	0.6-1.0	CLEAR
6-16-80	2345	C	N	-	10.5	8.5	8.5	VAR	10-15	VAR	0-0.3	CLEAR
6-16-80	1357	D	D	2.0	10.0	10.0	8.5	NW	15-20	NW	0.6-1.0	CLEAR
6-16-80	2330	D	N	-	10.0	7.5	7.5	VAR	10-15	VAR	0-0.3	CLEAR
6-16-80	1343	E	D	2.0	10.5	10.0	8.5	NW	15-20	NW	0.6-1.0	CLEAR
6-16-80	2320	E	N	-	10.0	7.0	7.0	VAR	10-15	VAR	0-0.3	CLEAR
6-16-80	1330	F	D	2.0	11.0	10.5	7.5	NW	15-20	NW	0.6-1.0	CLEAR
6-16-80	2300	F	N	-	10.0	7.0	6.5	VAR	10-15	VAR	0-0.3	CLEAR
6-16-80	1440	I	D	1.0	13.0	12.5	12.5	NW	20-25	NW	0.3-0.6	CLEAR
6-16-80	0012	I	N	-	11.5	11.5	11.5	VAR	0-5	CALM	CALM	HAZE
6-16-80	1416	J	D	1.5	10.7	10.7	10.7	NW	20-25	NW	0.3-0.6	CLEAR
6-16-80	2347	J	N	-	11.5	9.0	9.0	VAR	0-5	CALM	CALM	HAZE
6-16-80	1404	L	D	2.5	9.5	9.0	8.3	NW	20-25	NW	0.3-0.6	CLEAR
6-16-80	2332	L	N	-	11.0	7.3	7.3	VAR	0-5	CALM	CALM	HAZE
6-16-80	1353	N	D	2.8	11.0	11.0	7.4	NW	20-25	NW	0.3-0.6	CLEAR
6-16-80	2318	N	N	-	11.0	6.8	6.8	VAR	0-5	CALM	CALM	HAZE
6-16-80	1343	O	D	3.0	11.7	11.0	36.7	NW	20-25	NW	0.3-0.6	CLEAR
6-16-80	2306	O	N	-	10.0	6.8	6.8	VAR	0-5	CALM	CALM	HAZE
6-16-80	1455	P	D	0.75	13.0	13.0	13.0	NW	15-20	NW	0.6-1.0	CLEAR
6-17-80	0025	P	N	-	10.5	10.5	10.5	VAR	10-15	VAR	0-0.3	CLEAR
6-16-80	1528	Q	D	0.5	13.2	13.2	13.0	NW	20-25	NW	0.3-0.6	CLEAR
6-17-80	0045	Q	N	-	11.0	11.0	11.0	VAR	0-5	CALM	CALM	HAZE
6-16-80	1453	R	D	0.5	13.0	13.0	13.0	NW	20-25	NW	0.3-0.6	CLEAR
6-17-80	0028	R	N	-	11.5	11.5	11.5	VAR	0-5	CALM	CALM	HAZE
6-16-80	1336	W	D	3.0	12.3	11.0	7.3	NW	20-25	NW	0.3-0.6	CLEAR
6-16-80	2252	W	N	-	10.0	6.3	6.3	VAR	0-5	CALM	CALM	HAZE
7-01-80	1135	A	D	1.5	17.6	17.6	17.6	S	10-15	SW	0.6-1.0	PT. CLOUDY
7-01-80	0053	A	N	-	17.0	16.3	15.3	NE	0-5	CALM	CALM	HAZE
7-01-80	1144	B	D	1.5	17.6	17.5	17.4	S	10-15	SW	0.6-1.0	PT. CLOUDY
7-01-80	0028	B	N	-	17.0	17.0	15.3	NE	0-5	CALM	CALM	HAZE
7-01-80	1201	C	D	2.8	16.9	16.9	16.6	S	10-15	SW	0.6-1.0	PT. CLOUDY
7-01-80	0024	C	N	-	16.3	16.1	14.9	NE	,0-5	CALM	CALM	HAZE
7-01-80	1211	D	D	4.0	17.1	17.0	16.4	S	10-15	SW	0.6-1.0	PT. CLOUDY
7-01-80	0038	D	N	-	16.1	14.7	13.7	NE	0-5	CALM	CALM	HAZE
7-01-80	1222	E	D	3.5	16.9	16.9	16.5	S	10-15	SW	0.6-1.0	PT. CLOUDY
7-01-80	0053	E	N	-	16.2	14.1	13.1	NE	0-5	CALM	CALM	HAZE
7-01-80	1234	F	D	3.8	16.6	16.4	13.9	S	10-15	SW	0.6-1.0	PT. CLOUDY
7-01-80	0106	F	N	-	16.9	13.6	12.6	NE	0-5	CALM	CALM	HAZE
7-01-80	1351	I	D	2.0	17.1	17.1	17.1	SE	10-15	SW	0.6-1.0	PT. CLOUDY
7-01-80	0213	I	N	-	17.7	17.4	16.5	NE	0-5	VAR	0-0.1	HAZE
7-01-80	1337	J	D	2.7	16.6	16.6	17.0	SE	10-15	SW	0.6-1.0	PT. CLOUDY

Appendix 6. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	TEMPERATURE C SURFACE	MID DEPTH	BOTTOM	WIND DIR. FROM	SPEED (MPH)	WAVES DIR. FROM	HT. (M)	WEATHER
7-01-80	0152	J	N	-	17.6	17.2	16.0	NE	0-5	VAR	0-0.1	HAZE
7-01-80	1328	L	D	3.4	16.8	16.6	16.2	SE	10-15	SW	0.6-1.0	PT. CLOUDY
7-01-80	0203	L	N	-	16.5	14.9	13.5	NE	0-5	VAR	0-0.3	PT. CLOUDY
7-01-80	1318	M	D	3.5	16.4	16.1	15.9	SE	10-15	SW	0.6-1.0	PT. CLOUDY
7-01-80	0151	M	N	-	16.2	15.3	13.2	NE	0-5	VAR	0-0.3	PT. CLOUDY
7-01-80	1307	O	D	3.5	17.3	16.2	15.6	SE	10-15	SE	0.6-1.0	PT. CLOUDY
7-01-80	0138	O	N	-	16.7	16.1	13.5	NE	0-5	VAR	0-0.3	PT. CLOUDY
7-01-80	1500	P	D	BOTTOM	18.6	18.6	18.6	SW	5-10	SW	0.6-1.0	OVERCAST
7-01-80	0107	P	N	-	17.3	16.9	16.5	NE	0-5	CALM	CALM	HAZE
7-01-80	1545	Q	D	BOTTOM	18.4	18.4	18.4	SW	5-10	SW	0.6-1.0	OVERCAST
7-01-80	0134	Q	N	-	17.3	17.1	17.0	NE	0-5	VAR	0-0.1	HAZE
7-01-80	1625	R	D	BOTTOM	18.7	18.7	18.7	SW	5-10	SW	0.6-1.0	OVERCAST
7-01-80	0222	R	N	-	16.9	16.7	16.1	NE	0-5	VAR	0-0.1	HAZE
7-01-80	1255	W	D	3.7	16.6	16.2	16.2	SE	10-15	SW	0.6-1.0	PT. CLOUDY
7-01-80	0126	W	N	-	16.5	15.4	12.4	NE	0-5	VAR	0-0.3	PT. CLOUDY
7-15-80	1718	A	D	1.3	22.8	22.7	22.6	W	10-15	SW	0.6-1.0	PT. CLOUDY
7-14-80	2303	A	N	-	22.5	22.5	22.5	SW	10-15	SW	0.6-1.0	CLEAR
7-15-80	1700	B	D	1.4	22.8	22.0	22.0	SW	15-20	SW	0.6-1.0	PT. CLOUDY
7-14-80	2310	B	N	-	21.5	21.5	21.5	SW	10-15	SW	0.6-1.0	CLEAR
7-15-80	1648	C	D	1.5	22.8	21.5	20.9	SW	15-20	SW	0.6-1.0	PT. CLOUDY
7-14-80	2318	C	N	-	22.0	21.5	21.5	SW	10-15	SW	0.6-1.0	CLEAR
7-15-80	1637	D	D	3.25	21.5	21.1	20.8	SW	15-20	SW	0.6-1.0	PT. CLOUDY
7-14-80	2345	D	N	-	21.0	21.0	21.0	SW	10-15	SW	0.6-1.0	CLEAR
7-15-80	1624	E	D	3.5	21.3	20.8	20.8	SW	15-20	SW	0.6-1.0	PT. CLOUDY
7-15-80	0007	E	N	-	21.0	21.0	21.0	SW	10-15	SW	0.6-1.0	CLEAR
7-15-80	1603	F	D	4.0	21.0	20.0	13.7	SW	15-20	SW	0.6-1.0	PT. CLOUDY
7-15-80	0020	F	N	-	21.0	21.0	21.0	SW	10-15	SW	0.6-1.0	CLEAR
7-15-80	1717	I	D	1.25	22.3	22.3	22.0	W	0-5	WSW	1.0	PT. CLOUDY
7-15-80	2127	I	N	-	22.5	22.5	22.5	SW	15-20	SW	1.0	CLEAR
7-15-80	1657	J	D	2.5	22.5	22.0	22.0	W	0-5	WSW	1.0	PT. CLOUDY
7-16-80	0128	J	N	-	21.5	21.0	21.0	SW	15-20	SW	1.0	CLEAR
7-15-80	1630	L	D	3.5	22.1	21.0	20.8	W	0-5	WSW	1.0	PT. CLOUDY
7-16-80	0120	L	N	-	21.0	21.0	21.0	SW	15-20	SW	1.0	CLEAR
7-15-80	1618	M	D	3.0	21.6	20.5	20.4	W	0-5	WSW	1.0	PT. CLOUDY
7-16-80	0105	M	N	-	21.0	21.0	21.0	SW	15-20	SW	1.0	CLEAR
7-15-80	1607	O	D	2.75	21.6	20.5	20.1	W	0-5	WSW	1.0	PT. CLOUDY
7-16-80	0055	O	N	-	21.0	21.0	21.0	SW	15-20	SW	1.0	CLEAR
7-15-80	1728	P	D	1.0	22.8	22.8	22.8	W	10-15	SW	0.6-1.0	PT. CLOUDY
7-14-80	2225	P	N	-	22.5	22.5	22.5	SW	10-15	SW	0.6-1.0	CLEAR
7-15-80	1810	Q	D	BOTTOM	22.5	22.5	22.5	W	0-5	WSW	1.0	PT. CLOUDY
7-15-80	2212	Q	N	-	22.0	22.0	22.0	SW	15-20	SW	1.0	CLEAR
7-15-80	1743	R	D	BOTTOM	22.5	22.5	22.5	W	0-5	WSW	1.0	PT. CLOUDY
7-15-80	2140	R	N	-	22.2	22.2	22.2	SW	15-20	SW	1.0	CLEAR
7-15-80	1553	W	D	2.5	21.6	20.3	14.6	W	0-5	WSW	1.0	PT. CLOUDY
7-16-80	0035	W	N	2.5	20.5	20.5	20.5	SW	15-20	SW	1.0	CLEAR

Appendix 6. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	TEMPERATURE C SURFACE	MID DEPTH	BOTTOM	WIND DIR. FROM	SPEED (MPH)	WAVES DIR. FROM	HT. (M)	WEATHER
8-04-80	1853	A	D	BOTTOM	23.7	23.7	23.5	S	10-15	S	0.3-1.0	CLEAR
8-04-80	2356	A	N	-	22.7	22.7	22.5	SW	5-10	SW	0.3-0.6	PT. CLOUDY
8-04-80	1820	B	D	BOTTOM	24.0	24.0	23.9	S	10-15	S	0.3-1.0	CLEAR
8-04-80	2324	B	N	-	22.5	22.5	22.5	SW	5-10	SW	0.3-0.6	PT. CLOUDY
8-04-80	1806	C	D	5.0	23.9	23.7	23.7	S	10-15	S	0.3-1.0	CLEAR
8-04-80	2304	C	N	-	22.5	22.5	22.5	SW	5-10	SW	0.3-0.6	PT. CLOUDY
8-04-80	1752	D	D	6.0	23.8	23.0	18.0	S	10-15	S	0.3-1.0	CLEAR
8-04-80	2250	D	N	-	22.5	22.5	22.5	SW	5-10	SW	0.3-0.6	PT. CLOUDY
8-04-80	1734	E	D	6.0	23.7	22.5	13.5	S	10-15	S	0.3-1.0	CLEAR
8-04-80	2228	E	N	-	22.5	22.0	21.4	SW	5-10	SW	0.3-0.6	PT. CLOUDY
8-04-80	1636	F	D	6.0	23.7	21.5	10.4	S	10-15	S	0.3-1.0	CLEAR
8-04-80	2208	F	N	-	22.0	22.0	19.0	SW	5-10	SW	0.3-0.6	PT. CLOUDY
8-04-80	1806	I	D	BOTTOM	22.0	22.0	22.0	SSE	15-20	SE	0.3-0.6	CLEAR
8-04-80	2313	I	N	-	24.4	24.4	24.4	SW	10-15	SW	0.6	PT. CLOUDY
8-04-80	1742	J	D	4.0	22.0	22.0	21.5	SSE	15-20	SE	0.3-0.6	CLEAR
8-04-80	2251	J	N	-	23.3	23.3	23.3	SW	10-15	SW	0.6	PT. CLOUDY
8-04-80	1725	L	D	4.5	22.0	22.0	21.8	SSE	15-20	SE	0.3-0.6	CLEAR
8-04-80	2237	L	N	-	23.3	23.3	23.0	SW	10-15	SW	0.6	PT. CLOUDY
8-04-80	1707	N	D	4.3	22.3	22.0	21.5	SSE	15-20	SE	0.3-0.6	CLEAR
8-04-80	2225	N	N	-	22.8	22.8	22.8	SW	10-15	SW	0.6	PT. CLOUDY
8-04-80	1651	O	D	4.5	22.5	21.5	20.7	SSE	15-20	SE	0.3-0.6	CLEAR
8-04-80	2212	O	N	-	24.0	24.0	24.0	SW	10-15	SW	0.6	PT. CLOUDY
8-04-80	1905	P	D	BOTTOM	24.0	24.0	24.0	S	10-15	S	0.3-1.0	CLEAR
8-05-80	0025	P	N	-	22.7	22.7	22.5	SW	5-10	SW	0.3-0.6	PT. CLOUDY
8-04-80	1849	Q	D	BOTTOM	23.0	22.0	22.0	SSE	15-20	SE	0.3-0.6	CLEAR
8-04-80	2344	Q	N	-	23.5	23.5	23.3	SW	10-15	SW	0.6	PT. CLOUDY
8-04-80	1819	R	D	BOTTOM	23.0	22.5	22.5	SSE	15-20	SE	0.3-0.6	CLEAR
8-04-80	2328	R	N	-	23.3	23.3	23.3	SW	10-15	SW	0.6	PT. CLOUDY
8-04-80	1633	W	D	4.5	22.0	21.2	10.5	SSE	15-20	SE	0.3-0.6	CLEAR
8-04-80	2153	W	N	-	23.0	23.0	18.0	SW	10-15	SW	0.6	PT. CLOUDY
8-18-80	1350	A	D	BOTTOM	20.5	20.5	19.5	SW	0-5	W	0.3-0.6	CLEAR
8-18-80	2152	A	N	-	21.2	21.0	21.0	SW	0-5	SW	0-0.3	CLEAR
8-18-80	1400	B	D	2.5	20.1	19.8	18.9	SW	0-5	W	0.3-0.6	CLEAR
8-18-80	2130	B	N	-	20.5	19.5	17.2	SW	0-5	SW	0-0.3	CLEAR
8-18-80	1421	C	D	4.1	20.0	16.6	13.6	SW	0-5	W	0.3-0.6	CLEAR
8-18-80	2117	C	N	-	20.1	27.5	16.0	SW	0-5	SW	0-0.3	CLEAR
8-18-80	1432	D	D	4.3	20.0	16.6	10.8	SW	0-5	W	0.3-0.6	CLEAR
8-18-80	2105	D	N	-	20.2	16.5	14.3	SW	0-5	SW	0-0.3	CLEAR
8-18-80	1443	E	D	4.5	20.1	15.2	8.5	SW	0-5	W	0.3-0.6	CLEAR
8-18-80	2048	E	N	-	20.2	14.6	10.6	SW	0-5	SW	0-0.3	CLEAR
8-18-80	1456	F	D	4.5	20.7	14.6	7.4	SW	0-5	W	0.3-0.6	CLEAR
8-18-80	2036	F	N	-	20.6	16.3	8.4	SW	0-5	SW	0-0.3	CLEAR
8-18-80	1438	I	D	BOTTOM	19.3	19.3	19.3	WNW	5-10	WNW	0.3-0.6	CLEAR
8-18-80	2140	I	N	-	20.0	18.5	18.5	SW	5-10	WSW	0-0.3	HAZE
8-18-80	1427	J	D	BOTTOM	19.5	18.9	18.6	WNW	5-10	WNW	0.3-0.6	CLEAR

Appendix 6. Continued.

STARTING DATE	STARTING TIME	STATION	DIEL PERIOD	SECCHI DISC (M)	TEMPERATURE C SURFACE	MID DEPTH	BOTTOM	WIND DIR. FROM	SPEED (MPH)	WAVES DIR. FROM	HT. (M)	WEATHER
9-18-80	2122	J	N	-	20.5	17.0	17.0	SW	5-10	WSW	0-0.3	HAZE
8-18-80	1416	L	D	5.0	19.5	18.8	16.5	WNW	5-10	WNW	0.3-0.6	CLEAR
8-18-80	2113	L	N	-	20.0	19.0	16.7	SW	5-10	WSW	0-0.3	HAZE
8-18-80	1406	M	D	5.0	19.9	18.0	15.5	WNW	5-10	WNW	0.3-0.6	CLEAR
8-18-80	2103	M	N	-	20.3	18.1	15.3	SW	5-10	WSW	0-0.3	HAZE
8-18-80	1356	O	D	5.0	19.8	17.2	15.0	WNW	5-10	WNW	0.3-0.6	CLEAR
8-18-80	2054	O	N	-	20.2	17.5	10.6	SW	5-10	WSW	0-0.3	HAZE
8-18-80	1340	P	D	BOTTOM	21.0	21.0	21.0	SW	0-5	W	0.3-0.6	CLEAR
8-18-80	2205	P	N	-	20.8	20.8	20.8	SW	0-5	SW	0-0.3	CLEAR
8-18-80	1603	Q	D	BOTTOM	20.5	20.5	20.0	WNW	5-10	WNW	0.3-0.6	CLEAR
8-18-80	2214	Q	N	-	20.0	19.3	19.3	SW	5-10	WSW	0-0.3	HAZE
8-18-80	1449	R	D	BOTTOM	20.5	20.0	20.0	WNW	5-10	WNW	0.3-0.6	CLEAR
8-18-80	2148	R	N	-	20.0	18.5	18.5	SW	5-10	WSW	0-0.3	HAZE
8-18-80	1345	W	D	5.0	19.5	16.4	9.0	WNW	5-10	WNW	0.3-0.6	CLEAR
8-18-80	2041	W	N	-	20.2	18.0	7.8	SW	5-10	WSW	0-0.3	HAZE
9-15-80	1531	A	D	1.5	16.9	16.8	16.6	ESE	5-10	SE	0-0.3	OVERCAST
9-15-80	2236	A	N	-	18.0	18.0	18.0	S	10-15	S	0.3-0.6	OVERCAST
9-15-80	1512	B	D	2.75	16.7	16.4	14.7	ESE	5-10	SE	0-0.3	OVERCAST
9-15-80	2250	B	N	-	18.5	17.5	17.5	S	10-15	S	0.3-0.6	OVERCAST
9-15-80	1502	C	D	3.0	16.4	15.7	12.7	ESE	5-10	SE	0-0.3	OVERCAST
9-15-80	2311	C	N	-	17.0	16.5	13.4	S	10-15	S	0.3-0.6	OVERCAST
9-15-80	1452	D	D	2.75	17.2	15.2	10.2	ESE	5-10	SE	0-0.3	OVERCAST
9-15-80	2321	D	N	-	18.5	18.0	10.5	S	10-15	S	0.3-0.6	OVERCAST
9-15-80	1441	E	D	3.0	17.4	10.8	8.8	ESE	5-10	SE	0-0.3	OVERCAST
9-15-80	2330	E	N	-	17.3	14.8	8.1	S	10-15	S	0.3-0.6	OVERCAST
9-15-80	1430	F	D	2.75	17.5	11.0	7.5	ESE	5-10	SE	0-0.3	OVERCAST
9-15-80	2344	F	N	-	17.2	13.7	6.8	S	10-15	S	0.3-0.6	OVERCAST
9-15-80	1537	I	D	1.0	19.0	19.0	19.0	ESE	0-5	S	0-0.1	OVERCAST
9-15-80	2305	I	N	-	16.5	16.0	16.0	SE	10-15	SW	0.3-0.6	OVERCAST
9-15-80	1516	J	D	2.0	18.0	17.5	17.0	ESE	0-5	S	0-0.1	OVERCAST
9-15-80	2244	J	N	-	16.4	16.4	14.5	SE	10-15	SW	0.3-0.6	OVERCAST
9-15-80	1504	L	D	2.0	18.6	17.2	15.0	ESE	0-5	S	0-0.1	OVERCAST
9-15-80	2232	L	N	-	18.0	17.1	15.7	SE	10-15	SW	0.3-0.6	OVERCAST
9-15-80	1454	N	D	2.5	19.0	14.5	12.2	ESE	0-5	S	0-0.1	OVERCAST
9-15-80	2221	N	N	-	18.3	17.5	14.1	SE	10-15	SW	0.3-0.6	OVERCAST
9-15-80	1444	O	D	2.5	19.0	13.9	11.0	ESE	0-5	S	0-0.1	OVERCAST
9-15-80	2209	O	N	-	18.4	18.2	9.7	SE	10-15	SW	0.3-0.6	OVERCAST
9-15-80	1542	P	D	BOTTOM	17.4	17.4	17.4	ESE	5-10	SE	0-0.3	OVERCAST
9-15-80	2225	P	N	-	18.2	18.2	18.2	S	10-15	S	0.3-0.6	OVERCAST
9-15-80	1608	Q	D	BOTTOM	18.5	18.5	18.5	ESE	0-5	S	0-0.1	OVERCAST
9-15-80	2338	Q	N	-	16.3	16.3	16.3	SE	10-15	SW	0.3-0.6	OVERCAST
9-15-80	1547	R	D	1.0	18.3	18.3	18.0	ESE	0-5	S	0-0.1	OVERCAST
9-15-80	2316	R	N	-	16.5	16.5	16.5	SE	10-15	SW	0.3-0.6	OVERCAST
9-15-80	1430	W	D	2.5	20.0	17.0	10.0	ESE	0-5	S	0-0.1	OVERCAST
9-15-80	2151	W	N	-	18.5	18.3	7.5	SE	10-15	SW	0.3-0.6	OVERCAST

Appendix 7. Monthly length-frequency distributions of species caught during April to December 1980 in the J. H. Campbell Plant study area, Ottawa County, Michigan. Catches from all gear were pooled. Length intervals given represent the mid-point of a 10-mm length group.

ALEWIFE - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
20	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	2	1
30	0	0	0	0	0	0	0	0	208	872	1326	6	12	20	3	0	0	0	1549	898
40	0	0	0	0	0	0	0	0	46	671	1071	6	224	89	38	2	3	3	1382	771
50	0	0	0	0	0	0	0	0	1	3	228	5	711	40	107	7	15	9	1062	65
60	1	5	9	21	169	101	3	8	0	1	117	4	215	10	35	1	14	10	563	161
70	15	14	57	65	625	337	15	20	2	0	237	1	1252	0	3	0	1	0	2207	437
80	6	7	41	37	325	324	10	31	1	0	112	1	680	1	0	0	0	0	1175	401
90	3	2	2	7	96	76	3	54	0	1	37	3	19	0	0	0	0	0	160	143
100	0	0	0	2	13	22	7	197	0	3	76	19	13	0	0	0	0	0	109	243
110	0	0	0	0	9	12	1	104	8	9	54	20	2	0	0	0	0	0	74	145
120	0	0	0	0	3	2	0	16	3	4	67	2	0	0	0	0	0	0	73	24
130	0	1	0	0	4	3	1	2	0	0	106	1	0	0	0	0	0	0	111	7
140	0	0	0	0	19	2	0	15	0	1	35	1	0	0	0	0	0	0	54	19
150	0	0	0	6	116	56	0	68	6	7	39	6	0	0	0	0	0	0	161	143
160	3	5	1	22	214	137	6	177	51	24	69	13	0	0	0	1	0	0	344	379
170	11	9	4	43	432	198	10	515	35	37	117	14	0	0	0	0	0	0	639	816
180	21	13	0	25	356	207	10	376	20	13	58	17	0	2	0	0	0	0	465	653
190	10	10	0	14	56	72	5	106	5	8	3	1	0	1	0	0	0	0	79	212
200	9	4	0	13	36	44	1	43	0	1	2	0	0	0	0	1	0	0	48	106
210	1	2	0	4	23	40	0	38	1	0	1	1	0	0	0	0	0	0	26	85
220	0	0	0	3	0	11	0	14	0	0	0	0	0	0	0	0	0	0	0	28
230	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
240	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
250	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	80	72	114	262	2498	1644	72	1785	387	1655	3757	123	3129	163	186	12	33	22	10255	5738

BLACK CRAPPIE - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
210	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1

BLUEGILL - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
40	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
TOTALS	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1

Appendix 7. Continued.

BROWN TROUT - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
190	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
210	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
300	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
340	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
350	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
380	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1
390	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
400	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
410	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
430	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
440	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
450	0	1	0	1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	5
470	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
480	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	0	0	0	0	4
490	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	1	2
500	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
520	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	2
540	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
550	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
570	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
580	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
590	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
600	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
610	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
620	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
630	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
640	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
670	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
710	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	10	11	1	4	7	9	0	0	0	0	0	2	0	3	0	3	0	0	18	32

BURBOT - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
320	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
360	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
460	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
470	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
620	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
TOTALS	0	1	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	5

Appendix 7. Continued.

CARP - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
620	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
650	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
660	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
690	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	1	2
700	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1
710	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
720	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
750	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
770	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
780	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
TOTALS	0	1	0	0	0	1	2	3	1	1	0	0	0	3	0	2	0	0	3	11

CENTRAL MUDMINNOW - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
40	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
90	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

CHANNEL CATFISH - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
290	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
380	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
400	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
440	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
490	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
530	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2
550	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
600	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
730	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	1	0	0	0	0	0	0	1	4	0	4	0	0	0	0	0	0	1	9

Appendix 7. Continued.

CHINOOK SALMON - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
80	0	0	0	0	7	7	0	0	0	0	0	0	0	0	0	0	0	0	7	7
90	0	0	0	0	25	12	0	0	0	0	0	0	0	0	0	0	0	0	25	12
100	0	0	0	0	5	1	1	1	0	0	0	0	0	0	0	0	0	0	6	2
110	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
120	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
130	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
140	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
150	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
180	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	3
190	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3
200	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
230	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
250	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
300	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
340	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
370	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
510	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
670	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
700	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
730	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	2
740	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
760	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
800	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
810	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
880	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
890	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
910	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
920	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
950	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
980	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
990	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
1000	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
TOTALS	0	3	1	2	38	21	1	2	0	8	3	18	0	1	0	1	0	0	43	56

COHO SALMON - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
100	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
140	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
150	0	0	0	11	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	12
160	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21
170	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15
180	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
190	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
330	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
380	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
450	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
500	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
510	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
530	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
540	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
550	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
620	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
680	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
690	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
710	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
720	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
730	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
780	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
TOTALS	0	5	0	58	0	0	0	1	0	1	0	9	0	0	0	1	0	0	0	75

EMERALD SHINER - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
30	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	1	0	0	1	4
40	1	0	0	0	0	0	0	0	0	0	0	2	0	16	10	2	0	0	11	20
50	0	0	0	0	0	0	0	0	0	0	0	2	0	5	5	0	0	0	5	7
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0
70	0	0	0	0	0	0	0	0	1	15	1	2	0	3	1	0	0	0	3	20
80	0	0	0	0	0	0	0	0	5	44	19	14	0	4	4	0	0	0	28	62
90	0	0	0	0	0	0	0	0	0	15	12	54	0	1	2	0	0	0	14	70
TOTALS	1	0	0	0	0	0	0	0	6	74	32	75	0	31	25	3	0	0	64	183

FOURHORN SCULPIN - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
90	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

Appendix 7. Continued.

FRESHWATER DRUM - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
630	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
TOTALS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0

GIZZARD SHAD - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
50	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
60	0	0	0	0	0	0	0	0	1	5	0	0	0	1	0	0	0	0	1	6
70	0	0	0	0	0	0	0	0	0	5	0	0	1	0	0	0	0	0	1	5
80	0	0	0	0	0	0	0	0	1	10	0	0	1	2	0	0	0	0	2	12
90	0	0	0	0	0	0	0	0	0	5	0	0	2	2	0	0	0	0	2	7
100	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3
110	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
120	0	0	0	0	0	0	0	0	0	1	0	0	0	4	0	0	0	0	0	5
130	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
140	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2
230	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
270	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
280	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2
330	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
370	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
380	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
390	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
400	0	0	0	0	0	0	0	2	1	2	0	0	0	0	0	0	0	0	1	4
410	0	0	0	0	0	0	0	2	0	2	1	0	0	0	0	0	0	0	1	4
420	0	0	0	0	0	0	0	1	0	2	0	0	0	1	0	1	0	0	0	5
430	0	0	0	0	0	0	0	3	0	2	0	0	0	0	0	0	0	0	0	5
440	0	0	0	0	0	0	0	3	0	2	0	0	0	1	0	0	0	0	0	6
450	0	0	0	0	0	0	0	5	0	1	0	0	0	1	0	0	0	0	0	7
460	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	3
470	0	0	0	0	0	0	0	1	0	4	0	0	0	0	0	0	0	0	0	5
480	0	2	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	5
490	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0	0	0	4
510	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
TOTALS	0	2	0	0	0	1	0	22	6	45	2	4	4	21	0	4	0	0	12	99

GOLDEN REDHORSE - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
520	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
560	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1
570	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
TOTALS	0	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	0	0	2	2

Appendix 7. Continued.

GOLDEN SHINER - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
40	0	0	0	0	0	0	0	0	0	0	0	0	5	2	0	0	0	0	5	2
50	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	1	3
80	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
90	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3	0
TOTALS	0	0	0	0	0	0	0	0	0	0	0	0	10	5	0	0	0	0	10	5

JOHNNY DARTER - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	4
30	0	0	0	1	0	1	0	0	0	5	1	9	0	1	0	2	0	1	1	20
40	0	0	0	1	0	0	0	1	0	0	0	21	0	8	0	5	1	6	1	42
50	1	1	0	14	0	5	1	2	0	3	1	2	2	4	1	8	2	10	8	49
60	1	10	7	40	3	22	1	9	0	3	2	12	2	6	0	1	0	6	16	109
70	2	6	2	14	0	5	1	6	0	2	0	6	2	4	0	2	1	7	8	52
80	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3
TOTALS	4	18	9	71	3	34	3	18	0	16	4	50	6	23	1	19	4	30	34	279

LAKE HERRING - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
150	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1

LAKE TROUT - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
20	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
30	0	0	4	40	0	1	0	0	0	0	0	0	0	0	0	0	0	0	4	41
40	0	0	0	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	2	2
60	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	2	1
110	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
130	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
140	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
150	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
160	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
170	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1
190	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
280	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
330	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
470	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
490	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
510	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1
520	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
530	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
540	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	2
550	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
560	0	1	0	0	0	0	0	0	0	0	0	1	0	2	0	1	0	0	0	5
570	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	2
580	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3
590	0	0	0	2	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	5
600	0	0	0	0	0	1	0	0	0	0	0	1	0	2	0	1	0	0	0	5
610	0	1	0	1	1	0	0	0	0	0	0	5	0	4	0	1	0	0	1	12
620	0	0	1	0	0	0	0	0	0	0	0	1	0	2	0	2	0	0	1	5
630	0	1	0	0	0	1	0	0	0	0	2	4	0	6	0	5	0	0	2	17
640	0	1	0	0	1	1	0	0	0	0	0	0	0	4	0	3	0	0	1	9
650	0	1	0	0	0	0	0	0	0	0	0	2	0	5	0	7	0	0	0	15
660	0	2	0	0	0	0	0	0	0	0	1	4	0	13	0	6	0	0	1	25
670	0	0	0	1	1	1	0	0	0	0	0	0	0	14	4	10	0	0	5	26
680	0	3	0	0	2	0	0	0	0	0	0	2	0	16	0	9	0	0	2	30
690	1	0	0	0	0	1	0	0	0	0	0	5	1	16	0	10	0	0	2	32
700	0	0	0	0	0	2	0	0	0	1	0	2	0	16	2	5	0	0	2	26
710	0	0	0	0	1	1	0	0	0	0	0	2	0	17	4	7	0	0	5	27
720	0	1	0	0	1	0	0	0	0	0	1	2	0	9	0	8	0	0	2	20
730	0	0	0	0	0	0	0	0	0	1	0	4	0	6	0	5	0	0	0	16
740	0	0	0	0	0	0	0	0	0	1	1	5	2	10	0	3	0	0	3	19
750	1	0	0	0	1	0	0	0	0	0	0	2	4	13	2	3	0	0	8	18
760	0	0	0	0	0	0	0	0	0	0	0	3	0	5	0	11	0	0	0	19
770	0	1	0	0	0	0	0	0	0	0	0	1	0	13	0	3	0	0	0	18
790	0	0	0	0	0	0	0	0	0	0	0	1	0	7	0	2	0	0	0	10
790	0	0	0	0	0	1	0	0	0	0	0	2	2	4	0	2	0	0	2	9
800	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	4
810	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	3
820	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	3
830	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	1	0	0	0	5
840	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3
850	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	1
850	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
930	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
TOTALS	2	14	6	48	12	17	0	0	3	7	7	54	9	202	13	112	0	1	52	455

Appendix 7. Continued.

LAKE WHITEFISH - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
140	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
200	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
210	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
220	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
230	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2
250	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
260	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
270	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1
280	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
290	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2
300	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
350	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
360	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
370	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
380	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	3
390	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	2
400	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	3
410	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	1	0	0	0	4
420	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
430	0	0	0	0	0	0	0	0	0	2	0	3	0	0	0	0	0	0	0	5
440	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3
450	0	0	0	0	0	1	0	0	0	2	0	1	0	0	0	0	0	0	0	4
460	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	3
470	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
480	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3
490	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
510	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
530	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	3
540	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
550	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
560	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
570	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
580	0	0	0	0	0	1	0	0	0	2	0	1	0	0	0	0	0	0	0	4
620	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	3
630	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
670	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
680	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
700	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	1	1	0	3	0	13	0	1	1	35	1	16	0	1	0	2	0	0	3	72

LONGNOSE DACE - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
50	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
80	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
110	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	3

Appendix 7. Continued.

LONGNOSE SUCKER - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
70	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
120	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
170	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
230	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
250	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	3
300	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
310	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
330	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2
340	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
350	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2
360	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
370	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
380	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
390	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1
400	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	3
410	0	0	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	2	3
420	0	0	0	0	0	1	0	0	0	0	0	2	0	1	0	0	0	0	0	4
430	0	0	2	1	1	2	0	0	1	0	1	0	0	0	0	0	0	0	5	3
440	0	0	4	1	1	0	0	2	0	2	2	0	0	2	0	1	0	0	7	8
450	0	0	2	2	1	3	0	0	2	0	2	1	0	0	0	0	0	0	7	6
460	0	0	0	4	0	0	0	0	2	0	1	3	0	4	0	1	0	0	3	12
470	1	0	1	2	1	0	0	1	1	1	0	2	0	2	0	2	0	0	4	10
480	0	1	0	0	0	1	0	0	0	4	0	1	0	2	0	2	0	0	0	11
490	0	0	1	0	0	0	0	0	0	0	0	3	0	2	0	1	0	0	1	6
500	0	1	1	3	0	1	0	1	0	1	1	1	0	2	0	0	0	0	2	10
510	0	0	1	1	0	0	0	0	0	1	0	1	0	2	0	1	0	0	1	6
520	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
530	0	0	0	2	0	0	0	0	0	0	0	1	0	2	0	2	0	0	0	7
540	0	0	0	0	0	0	0	0	0	0	0	1	0	3	0	1	0	0	0	5
550	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2	0	0	0	4
560	0	0	0	0	0	0	0	0	0	1	0	3	0	1	0	0	0	0	0	5
580	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1
590	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3
620	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	2	6	15	20	7	14	0	10	6	12	9	25	0	26	0	14	0	0	39	127

MOTTLED SCULPIN - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
40	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	3
60	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
TOTALS	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0	0	0	5

Appendix 7. Continued.

NINESPINE STICKLEBACK - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
30	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
40	0	0	0	0	0	3	0	1	0	1	0	0	0	0	0	0	0	0	0	5
50	0	0	0	4	2	2	1	4	1	0	0	0	0	0	0	0	0	0	4	10
60	1	1	3	22	6	20	0	5	0	1	0	0	0	0	0	0	0	0	10	49
70	1	1	6	60	16	36	2	10	2	2	0	0	0	0	0	0	1	0	28	109
80	0	0	0	3	4	11	0	0	0	0	0	0	0	0	0	0	0	0	4	14
TOTALS	2	2	9	89	28	72	3	21	3	6	0	0	0	0	0	0	1	0	46	190

NORTHERN PIKE - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
770	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
TOTALS	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0

QUILLBACK - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
420	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
480	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
TOTALS	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	2

Appendix 7. Continued.

RAINBOW SMELT - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
30	0	0	0	0	0	0	29	23	385	1312	17	1	0	1	2	0	0	0	433	1337
40	2	5	2	1	0	0	137	22	3512	10839	421	585	156	66	95	44	29	19	4354	11580
50	105	100	151	211	100	26	11	1	485	982	499	912	1073	978	511	505	334	380	3269	3895
60	246	373	509	631	373	643	16	21	7	6	15	23	282	298	196	223	354	269	1998	2486
70	265	412	427	618	641	582	41	102	12	18	19	6	16	17	17	16	67	90	1505	1861
80	88	154	152	235	415	290	74	75	14	10	20	7	0	0	0	2	3	3	766	776
90	9	27	33	69	137	34	31	22	21	11	43	15	0	0	0	0	2	0	276	178
100	1	0	27	13	47	4	3	4	26	17	112	13	3	3	0	0	7	0	226	54
110	0	3	60	8	39	4	1	1	26	16	80	7	3	5	3	0	1	0	213	44
120	2	5	69	11	43	10	2	0	8	8	37	4	2	5	3	0	2	1	168	44
130	5	27	45	10	27	2	0	0	11	11	15	3	1	3	4	0	2	2	111	58
140	5	56	11	12	13	6	0	0	13	25	29	4	1	3	1	0	1	0	74	106
150	13	51	8	10	16	22	0	0	31	61	53	30	0	8	0	0	0	1	121	183
160	6	26	1	1	7	6	0	0	29	42	79	52	2	7	1	4	0	0	125	138
170	6	13	0	0	8	1	0	0	8	12	37	19	2	16	1	6	0	0	62	67
180	5	12	0	0	1	0	0	0	1	2	24	5	1	13	2	1	0	3	34	36
190	2	21	0	0	0	0	0	0	1	1	3	1	0	4	0	4	1	0	7	31
200	1	15	1	0	2	0	0	0	0	1	1	1	0	4	0	2	0	2	5	25
210	0	13	1	0	0	1	0	0	0	0	1	0	0	2	0	1	0	1	2	18
220	2	5	0	0	2	0	0	0	0	1	1	2	0	2	0	0	0	1	5	11
230	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
240	0	1	0	0	0	0	0	0	0	0	2	1	0	1	0	0	0	0	2	3
250	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3	0
260	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
TOTALS	763	1326	1497	1830	1871	1631	345	271	4590	13275	1512	1591	1542	1436	836	808	803	770	13759	22938

RAINBOW TROUT - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
270	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
370	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1
390	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
440	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
450	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
460	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
470	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
540	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
570	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
630	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
640	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
650	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2
660	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
670	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
680	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2
710	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
730	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	3
760	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
770	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
780	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
840	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
TOTALS	0	1	0	1	0	0	0	0	0	1	0	6	0	7	1	9	0	0	1	25

Appendix 7. Continued.

ROUND WHITEFISH - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
50	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
60	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
70	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	3	1
90	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1
100	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	1	2
120	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2
130	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	3
140	0	4	0	1	0	0	0	0	0	0	1	0	2	0	0	1	0	0	3	6
150	2	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	3	2
160	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1
170	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	3	1
180	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
190	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
210	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1
230	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
240	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3	0
250	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	1	2
260	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3
270	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
280	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0
290	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
300	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	2
310	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
330	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	1	2
340	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
350	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	3
370	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0	3	0	0	0	7
380	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	4
390	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	3
400	1	1	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	1	4
410	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	2
420	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	2	0	0	0	5
430	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0
440	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	2	3
450	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	2
460	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
470	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	4
480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
490	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0
500	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
520	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
TOTALS	7	9	1	5	1	6	5	3	2	7	2	5	9	22	6	21	2	2	35	80

Appendix 7. Continued.

SHORTHEAD REDHORSE - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
340	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
430	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
450	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
460	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
490	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2	0
590	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	0	0	0	0	2	0	0	2	1	1	0	0	1	0	0	0	0	3	4

SILVER REDHORSE - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
370	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
490	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
490	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
500	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
520	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2
540	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	3
550	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
560	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
570	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
610	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
TOTALS	0	0	0	0	0	1	0	2	0	6	2	3	0	0	0	0	0	0	2	12

SLIMY SCULPIN - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3
30	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
40	0	0	0	1	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	6
50	0	0	0	5	0	8	0	2	0	0	0	0	0	0	0	0	0	0	0	15
60	1	2	5	7	0	3	0	3	0	1	0	0	0	0	0	0	0	0	6	16
70	4	22	3	11	0	1	0	0	0	0	0	0	0	0	0	0	0	2	7	36
80	3	21	3	5	1	0	0	0	0	0	0	0	0	0	0	1	0	3	7	30
90	2	17	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	4	4	23
100	0	6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
TOTALS	10	69	12	32	1	17	0	7	0	1	0	1	0	0	0	2	2	10	25	139

Appendix 7. Continued.

SPOTTAIL SHINER - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
20	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0
30	0	1	1	0	0	0	0	0	72	7	3	4	0	5	1	0	0	1	77	18
40	1	0	2	2	0	1	0	0	159	15	200	152	16	77	3	3	0	9	380	259
50	1	4	5	7	8	16	0	1	1	0	275	252	139	396	14	67	10	50	453	793
60	0	0	10	22	29	43	6	4	0	0	59	24	65	274	7	26	5	36	181	429
70	0	0	4	7	11	24	12	13	0	1	11	24	0	24	0	4	0	1	38	98
80	1	3	6	14	5	144	39	22	0	2	2	8	1	6	0	1	0	1	54	201
90	0	1	11	19	10	460	120	171	0	1	3	63	1	65	0	5	0	1	145	786
100	1	3	50	90	88	1054	553	460	2	42	55	244	0	220	2	17	0	1	751	2131
110	2	3	43	134	148	1076	703	1258	11	153	393	500	2	415	0	49	0	9	1302	3596
120	0	9	18	57	112	430	305	680	2	86	297	370	3	407	0	28	0	4	737	2071
130	0	0	16	41	29	174	68	229	1	20	28	31	0	56	1	7	0	0	143	558
140	0	0	2	4	4	23	6	17	0	0	3	1	0	3	0	1	0	0	15	49
150	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
170	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
370	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
TOTALS	6	29	168	397	444	3445	1812	2855	249	328	1329	1673	227	1948	28	208	15	112	4278	10995

TROUT-PERCH - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
20	0	1	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	5
30	0	0	0	20	2	14	0	0	0	3	0	4	0	0	0	0	0	0	2	41
40	0	1	3	31	4	61	13	93	0	2	0	4	0	2	0	0	0	0	20	194
50	0	1	3	45	11	77	28	83	1	3	0	2	0	0	0	0	0	0	43	211
60	1	0	2	43	4	32	48	50	10	17	1	12	0	0	0	0	0	0	66	154
70	0	7	2	84	4	60	19	17	23	46	7	46	0	0	0	0	0	0	55	260
80	1	2	4	58	7	74	47	41	19	27	14	145	0	3	0	0	0	0	92	350
90	1	2	2	23	7	20	38	23	24	23	18	54	0	5	0	1	0	0	90	161
100	0	3	2	17	2	15	11	7	21	31	12	45	1	10	0	1	0	0	49	129
110	0	4	0	37	4	50	6	31	24	59	17	105	0	55	0	7	0	2	51	350
120	0	4	2	59	1	45	4	42	15	51	9	82	1	51	2	20	0	1	34	355
130	0	3	3	14	1	13	1	15	4	15	1	16	0	8	0	6	0	2	10	92
140	0	0	3	10	0	11	3	3	0	5	1	3	0	5	0	2	0	0	7	39
150	0	0	0	2	0	0	0	2	0	2	0	1	0	7	0	1	0	0	0	15
160	0	0	0	0	0	1	0	1	0	1	1	0	0	0	0	3	0	0	1	6
170	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	3
TOTALS	3	28	26	444	47	473	218	408	141	288	81	529	2	147	2	43	0	5	520	2365

UNIDENTIFIED COREGONINAE - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
50	0	0	0	0	0	0	0	0	0	0	25	3	18	4	0	0	0	0	43	7
60	0	1	0	4	0	0	0	0	0	0	111	9	119	31	19	6	7	9	256	59
70	0	1	24	43	12	19	1	2	0	1	80	25	562	184	183	64	239	180	1101	519
80	0	0	31	155	83	141	3	2	0	0	61	12	294	156	314	59	248	162	1034	687
90	0	0	31	177	189	273	23	38	2	3	2	5	8	11	38	4	39	11	332	522
100	0	0	14	82	124	287	59	98	9	36	1	0	0	0	0	0	0	0	207	503
110	0	0	0	25	30	127	86	144	44	78	4	0	0	0	0	0	0	0	164	374
120	0	0	1	3	10	23	27	113	69	223	10	13	0	0	0	0	0	0	117	375
130	0	0	0	3	0	14	4	74	28	83	33	45	0	0	0	0	0	0	65	219
140	0	0	0	1	6	19	0	8	5	11	16	35	0	0	0	0	0	0	27	74
150	0	0	2	18	40	53	0	4	0	0	9	32	0	0	0	0	0	0	51	107
160	0	0	2	45	66	225	0	13	0	0	1	6	0	0	0	0	0	0	69	289
170	0	0	2	43	136	297	0	5	0	0	6	9	0	0	0	0	0	0	144	354
180	0	0	0	21	137	300	0	2	0	0	12	23	0	0	0	0	0	0	149	346
190	0	0	0	11	46	214	0	3	0	0	7	57	0	0	0	0	0	0	53	285
200	0	0	0	3	26	84	0	1	0	1	17	58	0	0	0	0	0	0	43	147
210	0	0	0	0	8	29	0	0	0	0	7	48	0	0	0	0	0	0	15	77
220	0	0	0	0	5	20	0	0	0	0	5	20	0	0	0	0	0	0	10	40
230	0	0	0	0	3	11	0	0	0	0	3	17	0	0	0	0	0	0	6	28
240	0	0	0	0	1	5	0	0	0	2	1	10	0	0	0	0	0	0	2	17
250	0	0	0	0	2	2	0	0	0	0	1	6	0	0	0	0	0	0	3	8
260	0	0	0	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	4
270	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
310	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	2	107	634	924	2146	203	507	157	438	412	436	1001	386	554	133	533	361	3891	5043

WALLEYE - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
420	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
440	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
460	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
TOTALS	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	3

Appendix 7. Continued.

WHITE SUCKER - LAKE MICHIGAN

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
50	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
70	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
110	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
150	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
190	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
210	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2
220	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2
240	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2
250	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
260	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2
270	0	0	0	0	0	1	0	2	0	0	1	2	0	1	0	0	0	0	1	6
280	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	3
290	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2
300	0	0	0	0	0	1	0	3	0	1	1	0	0	0	0	1	0	0	1	6
310	0	0	0	0	1	1	0	1	0	2	1	1	0	0	0	1	0	0	2	6
320	0	0	0	0	1	0	0	1	0	1	0	2	0	1	0	0	0	0	1	5
330	0	0	0	1	0	2	0	1	0	5	1	0	0	1	0	0	0	0	1	10
340	0	0	0	0	0	1	0	0	0	5	0	1	0	0	0	0	0	0	0	7
350	0	0	0	1	0	3	0	4	1	5	0	2	0	0	0	0	0	0	1	15
360	0	0	0	0	1	1	0	2	0	4	1	2	0	1	0	0	0	0	2	10
370	0	0	1	0	1	1	0	3	0	4	1	3	0	1	0	1	0	0	3	13
380	0	0	0	1	0	6	0	1	1	6	0	6	0	1	0	2	0	0	1	23
390	0	0	0	0	0	4	0	2	0	5	1	3	0	2	0	1	0	0	1	17
400	0	0	0	0	0	0	1	1	0	11	0	2	0	1	0	0	0	0	1	15
410	0	0	1	1	1	1	0	1	0	2	3	9	0	2	0	1	0	0	5	17
420	0	0	1	3	0	2	0	2	1	5	0	6	0	1	0	0	0	0	2	19
430	0	0	0	2	1	0	0	1	0	3	0	9	0	3	0	1	0	0	1	19
440	0	0	0	0	0	3	0	1	0	3	1	4	0	2	0	1	0	0	1	13
450	0	0	1	2	0	2	0	1	0	6	1	4	0	0	0	2	0	0	2	17
460	0	0	0	3	0	1	0	0	0	1	1	7	0	1	0	0	0	0	1	13
470	0	0	0	2	0	3	0	0	1	1	0	4	0	0	1	0	0	0	2	10
480	0	0	1	2	0	3	0	1	1	6	0	6	0	0	0	0	0	0	2	18
490	0	0	1	2	1	3	0	0	0	2	2	3	0	1	0	0	0	0	4	11
500	0	0	2	0	0	1	0	0	0	0	0	3	0	2	0	0	0	0	2	6
510	0	0	1	1	0	2	0	0	0	0	0	0	0	2	0	0	0	0	1	5
520	0	0	0	3	1	0	0	0	0	2	1	2	0	0	2	0	0	0	4	7
530	0	0	0	0	1	1	0	0	0	1	1	3	0	1	0	0	0	0	2	6
540	0	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	0	0	1	3
550	0	0	1	2	1	0	0	1	0	0	1	6	0	0	0	1	0	0	3	10
560	0	0	0	0	0	1	0	0	1	0	1	1	0	1	0	0	0	0	2	3
570	0	0	0	4	0	0	0	0	0	3	0	3	0	0	0	0	0	0	0	10
580	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
600	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
TOTALS	0	0	11	31	11	47	3	33	6	86	20	100	0	30	3	11	0	0	54	338

Appendix 7. Continued.

YELLOW BULLHEAD - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
180	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
TOTALS	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2

YELLOW PERCH - LAKE MICHIGAN

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
30	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
40	0	0	0	0	0	0	0	0	8	10	3	1	0	0	0	0	0	0	11	11
50	0	1	0	0	0	0	0	0	128	23	4	1	0	0	0	0	0	0	132	25
60	0	0	0	0	0	1	0	0	48	6	12	46	0	1	1	0	0	0	61	54
70	2	0	0	2	1	2	0	0	0	0	35	116	2	8	0	1	0	3	40	132
80	2	4	0	3	1	1	1	0	0	0	18	135	13	26	1	1	2	0	38	170
90	1	1	0	0	0	1	0	1	0	0	0	14	9	15	0	0	0	0	10	32
100	0	0	0	0	1	0	3	1	0	0	0	0	0	4	0	0	0	0	4	5
110	0	0	0	0	0	2	6	1	0	3	0	1	0	0	0	0	0	0	6	7
120	1	1	0	0	0	1	3	0	2	4	2	2	0	0	0	0	0	0	8	8
130	0	1	0	1	0	1	10	1	2	5	1	4	0	1	0	0	0	0	13	14
140	0	1	0	0	1	5	19	7	1	3	12	16	0	0	2	0	0	0	35	32
150	0	3	1	3	0	3	57	8	18	14	42	21	0	1	0	0	0	0	118	53
160	0	1	0	0	1	1	25	12	33	30	14	14	0	3	0	2	0	0	73	63
170	1	0	0	0	0	0	13	7	23	19	36	34	0	0	0	0	0	0	73	60
180	0	2	0	0	0	2	5	3	13	7	32	17	0	0	0	2	0	0	50	33
190	0	2	0	1	0	1	2	5	10	6	27	8	0	1	0	0	0	0	39	24
200	0	0	0	0	0	2	5	5	7	9	13	11	0	1	0	1	0	0	25	29
210	0	0	0	0	1	0	5	1	5	8	9	7	0	0	0	0	0	0	20	16
220	0	0	0	2	1	4	5	1	4	5	2	7	0	0	0	0	0	0	12	19
230	0	0	0	0	0	4	2	5	8	8	12	4	0	0	0	0	0	0	22	21
240	1	0	0	0	1	0	1	2	9	14	14	6	0	0	0	0	0	0	26	22
250	0	0	0	0	0	1	1	1	4	1	9	7	0	0	0	0	0	0	14	10
260	0	0	0	0	1	1	0	0	1	4	3	4	0	0	1	0	0	0	6	9
270	0	0	0	1	0	0	2	1	0	0	1	0	0	0	0	0	0	0	3	2
280	0	0	0	0	0	0	1	0	2	1	3	3	0	0	0	0	0	0	6	4
290	0	0	0	0	0	0	0	1	2	1	2	0	0	1	0	0	0	0	4	3
300	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2
310	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	3
320	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
340	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	8	17	1	14	9	33	166	64	328	185	306	481	24	62	5	7	2	3	949	866

Appendix 8. Monthly length-frequency distributions of most abundant species caught in Lake Michigan during 1980 in the vicinity of the J. H, Campbell Plant, Ottawa County, Michigan. Distributions were segregated by gear type. Length intervals given represent the mid-point of a 10-mm length group.

RAINBOW SMELT

LAKE MICHIGAN - SEINES

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
30	0	0	0	0	0	0	0	0	1	12	0	1	0	0	0	0	0	0	1	13
40	0	0	0	0	0	0	0	0	0	30	2	61	0	0	0	0	0	0	2	91
50	0	0	0	1	0	0	0	0	0	0	1	23	0	4	1	0	0	0	2	28
60	0	1	0	41	3	41	0	0	0	0	0	1	1	1	2	1	0	0	6	86
70	0	1	0	119	1	36	0	0	0	0	0	0	0	0	0	0	0	0	1	156
80	0	0	0	99	0	8	0	0	0	1	0	0	0	0	0	0	0	0	0	108
90	0	0	0	56	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	57
100	0	0	0	7	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	8
110	0	0	0	4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	5
120	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3
130	0	0	0	1	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	4
150	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
160	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	4
TOTALS	0	2	0	330	4	87	0	0	1	47	3	93	1	5	3	1	0	0	12	565

LAKE MICHIGAN - TRAWLS

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
30	0	0	0	0	0	0	29	23	384	1300	17	0	0	1	2	0	0	0	432	1324
40	2	5	2	1	0	0	137	22	3512	10809	419	524	156	66	95	44	29	18	4352	11489
50	105	100	151	210	100	26	11	1	485	892	498	789	1073	974	510	505	334	380	3267	3867
60	246	372	509	590	370	602	16	21	7	6	15	22	281	297	194	222	354	268	1992	2400
70	265	411	427	499	640	546	41	102	12	18	19	6	16	17	17	16	67	90	1504	1705
80	88	154	152	136	415	282	74	75	14	9	20	7	0	0	0	2	3	3	766	668
90	9	27	33	13	137	33	31	22	21	10	43	15	0	0	0	0	2	0	276	120
100	1	0	27	6	47	4	3	4	24	15	112	13	3	3	0	0	7	0	224	45
110	0	3	60	4	39	4	1	1	23	14	80	7	3	5	3	0	1	0	210	38
120	2	1	69	9	43	9	2	0	5	6	37	3	2	5	3	0	2	1	165	34
130	4	2	45	3	26	2	0	0	9	6	16	2	1	3	4	0	2	2	107	20
140	3	3	10	1	13	1	0	0	6	13	26	1	0	0	1	0	1	0	60	19
150	11	5	6	0	7	1	0	0	1	11	18	1	0	5	0	0	0	1	43	24
160	5	3	1	0	1	0	0	0	1	5	9	1	2	0	0	1	0	0	19	10
170	5	2	0	0	1	0	0	0	0	2	4	0	1	3	1	3	0	0	12	10
180	3	0	0	0	0	0	0	0	0	1	2	1	1	3	2	1	0	3	8	9
190	2	0	0	0	0	0	0	0	0	1	0	0	0	1	0	3	1	0	3	5
200	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	2	4
210	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
220	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1
TOTALS	753	1088	1494	1472	1840	1510	345	271	4504	13108	1335	1392	1539	1383	832	799	803	770	13445	21793

Appendix 8. Continued.

RAINBOW SMELT

LAKE MICHIGAN - BOTTOM GILL NETS

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
100	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	2	1
110	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	3	1
120	0	4	0	0	0	0	0	0	3	2	0	1	0	0	0	0	0	0	3	7
130	1	25	0	3	1	0	0	0	2	3	0	0	0	0	0	0	0	0	4	31
140	2	52	1	6	0	0	0	0	7	10	3	2	1	3	0	0	0	0	14	73
150	2	44	2	4	9	8	0	0	30	42	35	13	0	3	0	0	0	0	78	114
160	1	23	0	1	6	2	0	0	28	33	73	18	0	7	1	3	0	0	106	87
170	1	11	0	0	7	1	0	0	8	7	33	11	1	13	0	3	0	0	50	46
180	2	12	0	0	1	0	0	0	1	1	22	4	0	10	0	0	0	0	26	27
190	0	20	0	0	0	0	0	0	1	0	3	0	0	3	0	1	0	0	4	24
200	0	15	0	0	2	0	0	0	0	1	1	0	0	4	0	0	0	0	3	20
210	0	11	0	0	0	1	0	0	0	0	1	0	0	2	0	1	0	0	1	15
220	1	5	0	0	1	0	0	0	0	1	1	1	0	2	0	0	0	0	3	9
230	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
240	0	1	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	2	2
250	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3	0
260	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
TOTALS	10	230	3	14	27	12	0	0	85	102	174	50	2	48	1	8	0	0	302	464

LAKE MICHIGAN - SURFACE GILL NETS

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
90	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
130	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
140	0	1	0	5	0	5	0	0	0	2	0	1	0	0	0	0	0	0	0	14
150	0	2	0	6	0	13	0	0	0	8	0	14	0	0	0	0	0	0	0	43
160	0	0	0	0	0	4	0	0	0	4	0	29	0	0	0	0	0	0	0	37
170	0	0	0	0	0	0	0	0	0	3	0	8	0	0	0	0	0	0	0	11
190	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
200	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
210	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
220	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
240	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
TOTALS	0	6	0	14	0	22	0	0	0	18	0	56	0	0	0	0	0	0	0	116

Appendix 8. Continued.

ALEWIFE

LAKE MICHIGAN - SEINES

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0
30	0	0	0	0	0	0	0	0	206	871	1326	0	0	17	0	0	0	0	1532	889
40	0	0	0	0	0	0	0	0	43	669	1071	2	0	77	0	0	0	0	1114	748
50	0	0	0	0	0	0	0	0	0	3	228	5	0	27	0	0	0	0	229	35
60	0	0	0	13	113	88	0	2	0	1	26	1	0	6	0	0	0	0	139	111
70	0	1	0	19	422	187	0	9	1	0	0	0	0	0	0	0	0	0	423	216
80	0	0	0	9	174	167	0	26	0	0	0	0	0	0	0	0	0	0	174	202
90	0	0	0	4	21	31	0	14	0	0	0	0	0	0	0	0	0	0	21	49
100	0	0	0	0	1	9	0	1	0	0	0	0	0	0	0	0	0	0	1	10
110	0	0	0	0	0	3	0	0	0	1	0	0	0	0	0	0	0	0	0	4
130	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	3
140	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	14
150	0	0	0	1	0	6	0	22	0	1	0	0	0	0	0	0	0	0	0	30
160	0	0	0	0	0	27	0	45	0	3	0	0	0	0	0	0	0	0	0	75
170	0	0	0	0	0	19	0	47	0	1	0	0	0	0	0	0	0	0	0	67
180	0	0	0	0	0	32	0	82	0	4	0	2	0	0	0	0	0	0	0	120
190	0	0	0	0	0	19	0	15	0	0	0	0	0	0	0	0	0	0	0	34
200	0	0	0	0	0	8	0	4	0	0	0	0	0	0	0	0	0	0	0	12
210	0	0	0	0	0	6	0	1	0	0	0	0	0	0	0	0	0	0	0	7
220	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	1	0	46	731	605	0	283	250	1554	2653	10	0	127	0	0	0	0	3634	2626

LAKE MICHIGAN - TRAWLS

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
30	0	0	0	0	0	0	0	0	2	1	0	6	12	3	3	0	0	0	17	10
40	0	0	0	0	0	0	0	0	3	2	0	4	224	12	38	2	3	3	268	23
50	0	0	0	0	0	0	0	0	1	0	0	1	711	13	107	7	15	9	834	30
60	1	5	9	8	56	13	3	6	0	0	91	3	215	4	35	1	14	10	424	50
70	15	13	57	46	203	150	15	11	1	0	237	1	1252	0	3	0	1	0	1784	221
80	6	7	41	28	151	157	10	4	1	0	112	1	680	1	0	0	0	0	1001	198
90	3	2	2	3	75	45	3	3	0	0	37	1	17	0	0	0	0	0	137	54
100	0	0	0	2	11	6	7	5	0	0	73	1	0	0	0	0	0	0	91	14
110	0	0	0	0	5	1	0	0	1	0	45	1	0	0	0	0	0	0	52	2
120	0	0	0	0	1	0	0	0	2	0	59	0	0	0	0	0	0	0	62	0
130	0	1	0	0	3	0	0	0	0	0	104	0	0	0	0	0	0	0	107	1
140	0	0	0	0	7	1	0	0	0	0	35	0	0	0	0	0	0	0	42	1
150	0	0	0	0	13	5	0	1	2	0	21	0	0	0	0	0	0	0	36	6
160	3	4	0	0	15	5	2	9	23	3	23	1	0	0	0	0	0	0	66	22
170	11	0	1	0	39	19	5	21	12	2	56	0	0	0	0	0	0	0	124	51
180	20	13	0	0	51	24	6	12	16	0	34	0	0	0	0	0	0	0	127	49
190	9	10	0	0	9	14	2	17	4	0	2	0	0	0	0	0	0	0	26	41
200	8	4	0	0	12	5	1	7	0	0	1	0	0	0	0	0	0	0	22	16
210	0	2	0	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0	3	3
TOTALS	76	70	110	87	653	446	54	96	69	8	931	21	3111	33	186	10	33	22	5223	793

ALEWIFE

LAKE MICHIGAN - BOTTOM GILL NETS

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
90	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	2	1
100	0	0	0	0	1	1	0	41	0	1	3	0	13	0	0	0	0	0	17	43
110	0	0	0	0	4	2	1	64	0	2	8	5	2	0	0	0	0	0	15	73
120	0	0	0	0	2	0	0	1	1	3	8	0	0	0	0	0	0	0	11	4
130	0	0	0	0	1	0	1	1	0	0	2	1	0	0	0	0	0	0	4	2
140	0	0	0	0	12	1	0	0	0	1	0	0	0	0	0	0	0	0	12	2
150	0	0	0	4	103	9	0	37	4	6	18	1	0	0	0	0	0	0	125	57
160	0	1	1	6	198	16	4	111	28	11	46	3	0	0	0	1	0	0	277	149
170	0	0	3	14	393	40	5	329	23	19	61	0	0	0	0	0	0	0	485	402
180	1	0	0	10	303	22	4	216	4	5	24	1	0	2	0	0	0	0	336	256
190	1	0	0	2	47	10	3	66	1	5	1	0	0	1	0	0	0	0	53	84
200	1	0	0	8	24	9	0	30	0	0	1	0	0	0	0	0	0	0	26	47
210	1	0	0	2	20	8	0	34	0	0	1	0	0	0	0	0	0	0	22	44
220	0	0	0	0	0	7	0	11	0	0	0	0	0	0	0	0	0	0	0	18
230	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
240	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
250	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	4	1	4	46	1110	125	18	942	61	54	173	11	17	3	0	1	0	0	1387	1183

LAKE MICHIGAN - SURFACE GILL NETS

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
80	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
90	0	0	0	0	0	0	0	37	0	0	0	2	0	0	0	0	0	0	0	39
100	0	0	0	0	0	6	0	150	0	2	0	18	0	0	0	0	0	0	0	176
110	0	0	0	0	0	6	0	40	7	6	0	14	0	0	0	0	0	0	7	66
120	0	0	0	0	0	2	0	15	0	1	0	2	0	0	0	0	0	0	0	20
130	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
140	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2
150	0	0	0	1	0	36	0	8	0	0	0	5	0	0	0	0	0	0	0	50
160	0	0	0	16	1	89	0	12	0	7	0	9	0	0	0	0	0	0	1	133
170	0	0	0	29	0	120	0	118	0	15	0	14	0	0	0	0	0	0	0	296
180	0	0	0	15	2	129	0	66	0	4	0	14	0	0	0	0	0	0	2	228
190	0	0	0	12	0	29	0	8	0	3	0	1	0	0	0	0	0	0	0	53
200	0	0	0	5	0	22	0	2	0	1	0	0	0	0	0	1	0	0	0	31
210	0	0	0	2	1	25	0	3	0	0	0	1	0	0	0	0	0	0	1	31
220	0	0	0	3	0	3	0	3	0	0	0	0	0	0	0	0	0	0	0	9
TOTALS	0	0	0	83	4	468	0	464	7	39	0	81	0	0	0	1	0	0	11	1136

Appendix 8. Continued.

SPOTTAIL SHINER

Lake Michigan - Seines

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0
30	0	0	1	0	0	0	0	0	72	7	3	4	0	2	1	0	0	0	77	13
40	0	0	1	0	0	1	0	0	158	15	196	40	0	9	0	0	0	0	355	65
50	0	1	2	0	7	0	0	1	1	0	275	27	1	5	0	0	0	0	286	34
60	0	0	2	0	24	1	5	3	0	0	59	1	0	5	0	0	0	0	90	10
70	0	0	0	0	10	0	12	3	0	1	11	7	0	1	0	0	0	0	33	12
80	1	1	0	2	5	1	33	2	0	2	1	0	0	2	0	0	0	0	40	10
90	0	0	3	3	8	6	88	10	0	0	0	5	0	3	0	0	0	0	99	27
100	0	0	30	32	27	26	48	26	0	18	1	13	0	18	0	0	0	0	106	133
110	0	0	21	39	16	19	30	17	0	17	1	11	0	11	0	1	0	0	68	115
120	0	0	13	9	4	11	1	2	0	4	0	0	0	12	0	0	0	0	18	38
130	0	0	13	10	1	4	0	2	0	0	0	0	0	5	0	0	0	0	14	21
140	0	0	1	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	1	3
TOTALS	1	2	87	95	102	71	217	67	233	64	547	108	1	73	1	1	0	0	1189	481

Lake Michigan - Trawls

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
30	0	1	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	5
40	1	0	1	2	0	0	0	0	0	0	4	112	16	68	3	3	0	9	25	194
50	1	3	3	7	1	16	0	0	0	0	0	225	138	391	14	67	10	50	167	759
60	0	0	8	22	5	42	1	1	0	0	0	23	65	269	7	26	5	36	91	419
70	0	0	4	7	1	24	0	10	0	0	0	17	0	23	0	4	0	1	5	86
80	0	2	6	12	0	143	6	20	0	0	1	8	1	4	0	1	0	1	14	191
90	0	1	8	16	2	451	32	161	0	1	3	58	1	62	0	5	0	1	46	756
100	1	3	18	50	4	908	496	323	2	15	4	201	0	188	1	17	0	1	526	1706
110	1	1	16	39	5	754	401	371	7	16	15	335	2	330	0	22	0	8	447	1876
120	0	6	2	11	0	312	133	148	0	8	11	283	2	291	0	5	0	4	148	1068
130	0	0	2	8	0	105	33	69	1	1	1	11	0	40	0	1	0	0	37	235
140	0	0	1	2	0	19	3	4	0	0	0	1	0	3	0	0	0	0	4	29
TOTALS	4	17	69	176	18	2774	1105	1107	10	41	39	1274	225	1672	25	151	15	112	1510	7324

Lake Michigan - Bottom Gill Nets

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
90	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3
100	0	0	2	8	57	120	9	109	0	9	50	29	0	14	1	0	0	0	119	289
110	1	2	6	56	127	303	272	858	4	107	377	154	0	74	0	26	0	0	787	1580
120	0	3	3	37	108	107	171	522	2	69	286	87	1	104	0	23	0	0	571	952
130	0	0	1	23	28	65	35	156	0	16	27	20	0	11	1	6	0	0	92	297
140	0	0	0	2	4	2	3	12	0	0	3	0	0	0	0	1	0	0	10	17
150	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
170	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
370	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
TOTALS	1	10	12	126	324	600	490	1657	6	202	743	290	1	203	2	56	0	0	1579	3144

Lake Michigan - Surface Gill Nets

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
100	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	3
110	0	0	0	0	0	0	0	12	0	13	0	0	0	0	0	0	0	0	0	25
120	0	0	0	0	0	0	0	8	0	5	0	0	0	0	0	0	0	0	0	13
130	0	0	0	0	0	0	0	2	0	3	0	0	0	0	0	0	0	0	0	5
TOTALS	0	0	0	0	0	0	0	24	0	21	0	1	0	0	0	0	0	0	0	46

UNIDENTIFIED COREGONINAE

LAKE MICHIGAN - SEINES

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
50	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	25	0
60	0	0	0	0	0	0	0	0	0	0	111	0	0	0	0	0	0	0	111	0
70	0	0	0	0	0	0	0	0	0	0	65	0	0	0	0	0	0	0	65	0
80	0	0	0	0	0	2	0	0	0	0	34	0	0	0	0	0	0	0	34	2
90	0	0	0	0	10	0	0	0	0	0	1	0	0	0	0	0	0	0	11	0
100	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
110	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
120	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
TOTALS	0	0	0	0	14	2	0	0	0	0	236	0	0	0	0	0	0	0	250	2

LAKE MICHIGAN - TRAWLS

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
50	0	0	0	0	0	0	0	0	0	0	0	3	18	4	0	0	0	0	18	7
60	0	1	0	4	0	0	0	0	0	0	0	9	119	31	19	6	7	8	145	59
70	0	1	24	43	12	19	1	2	0	1	15	25	562	184	183	64	239	180	1036	519
80	0	0	31	155	83	139	3	2	0	0	27	12	294	156	314	59	248	162	1000	685
90	0	0	31	177	179	273	23	18	2	3	1	5	8	11	38	4	39	11	321	522
100	0	0	14	82	122	287	59	97	9	36	1	0	0	0	0	0	0	0	205	507
110	0	0	0	25	29	123	86	143	44	76	4	0	0	0	0	0	0	0	163	367
120	0	0	1	3	8	19	26	105	68	207	10	10	0	0	0	0	0	0	113	344
130	0	0	0	3	0	14	4	71	28	75	27	33	0	0	0	0	0	0	59	196
140	0	0	0	1	4	18	0	7	5	11	14	19	0	0	0	0	0	0	23	56
150	0	0	2	19	31	44	0	4	0	0	8	23	0	0	0	0	0	0	41	89
160	0	0	2	44	52	220	0	13	0	0	1	3	0	0	0	0	0	0	55	280
170	0	0	1	40	118	260	0	5	0	0	6	6	0	0	0	0	0	0	125	311
180	0	0	0	21	97	216	0	2	0	0	9	15	0	0	0	0	0	0	106	254
190	0	0	0	9	21	142	0	3	0	0	4	35	0	0	0	0	0	0	25	189
200	0	0	0	3	12	66	0	1	0	0	13	37	0	0	0	0	0	0	25	107
210	0	0	0	0	2	18	0	0	0	0	0	28	0	0	0	0	0	0	2	46
220	0	0	0	0	1	10	0	0	0	0	3	12	0	0	0	0	0	0	4	22
230	0	0	0	0	0	5	0	0	0	0	1	6	0	0	0	0	0	0	1	11
240	0	0	0	0	0	4	0	0	0	0	0	4	0	0	0	0	0	0	0	8
250	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
260	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
TOTALS	0	2	106	628	771	1878	202	493	156	409	144	296	1301	386	554	133	533	361	3467	4576

UNIDENTIFIED COREGONINAE

LAKE MICHIGAN - BOTTOM GILL NETS

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
100	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
110	0	0	0	0	0	4	0	1	0	2	0	0	0	0	0	0	0	0	0	7
120	0	0	0	0	1	4	1	8	1	15	0	3	0	0	0	0	0	0	3	30
130	0	0	0	0	0	3	0	3	0	8	6	12	0	0	0	0	0	0	6	23
140	0	0	0	0	2	1	0	1	0	0	2	16	0	0	0	0	0	0	4	18
150	0	0	0	0	9	9	0	0	0	0	1	9	0	0	0	0	0	0	10	18
160	0	0	0	1	14	5	0	0	0	0	0	3	0	0	0	0	0	0	14	9
170	0	0	1	3	18	37	0	0	0	0	0	3	0	0	0	0	0	0	19	43
180	0	0	0	0	40	82	0	0	0	0	3	8	0	0	0	0	0	0	43	90
190	0	0	0	2	25	70	0	0	0	0	3	22	0	0	0	0	0	0	28	94
200	0	0	0	0	14	18	0	0	0	1	4	21	0	0	0	0	0	0	18	40
210	0	0	0	0	6	11	0	0	0	0	7	20	0	0	0	0	0	0	13	31
220	0	0	0	0	4	10	0	0	0	0	2	8	0	0	0	0	0	0	6	18
230	0	0	0	0	3	6	0	0	0	0	2	11	0	0	0	0	0	0	5	17
240	0	0	0	0	1	1	0	0	0	2	1	6	0	0	0	0	0	0	2	9
250	0	0	0	0	2	1	0	0	0	0	1	6	0	0	0	0	0	0	3	7
260	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	3
270	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
310	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	0	1	6	139	262	1	14	1	28	32	150	0	0	0	0	0	0	174	460

LAKE MICHIGAN - SURFACE GILL NETS

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
120	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
180	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
190	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
TOTALS	0	0	0	0	0	4	0	0	0	1	0	0	0	0	0	0	0	0	0	5

Appendix 8. Continued.

TROUT-PERCH

LAKE MICHIGAN - SEINES

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
60	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
70	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
80	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
100	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
110	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
120	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2
130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
TOTALS	0	0	0	4	0	1	0	0	0	0	0	1	0	3	0	1	0	0	0	10

LAKE MICHIGAN - TRAWLS

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	1	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	5
30	0	0	0	20	2	14	0	0	0	3	0	4	0	0	0	0	0	0	2	41
40	0	1	3	31	4	61	13	93	0	2	0	4	0	2	0	0	0	0	20	194
50	0	1	3	45	11	77	28	83	1	3	0	2	0	0	0	0	0	0	43	211
60	1	0	2	41	4	32	48	50	10	17	1	12	0	0	0	0	0	0	66	152
70	0	7	2	83	4	60	19	17	23	46	7	46	0	0	0	0	0	0	55	259
80	1	2	4	57	7	74	47	41	19	27	14	145	0	3	0	0	0	0	92	349
90	1	2	2	23	7	20	38	23	24	23	18	64	0	5	0	1	0	0	90	161
100	0	3	2	17	2	14	11	7	21	31	11	45	1	8	0	1	0	0	48	126
110	0	4	0	32	3	48	6	31	24	55	16	95	0	22	0	4	0	2	49	293
120	0	3	2	49	1	39	4	32	15	48	7	70	1	21	0	11	0	1	30	274
130	0	2	3	13	0	13	1	15	4	14	0	13	0	5	0	4	0	2	8	81
140	0	0	3	10	0	11	3	3	0	5	1	3	0	5	0	1	0	0	7	38
150	0	0	0	2	0	0	0	2	0	2	0	1	0	6	0	1	0	0	0	14
160	0	0	0	0	0	1	0	1	0	1	1	0	0	0	0	2	0	0	1	5
170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
TOTALS	3	26	26	424	45	464	218	398	141	280	76	504	2	77	0	26	0	5	511	2204

LAKE MICHIGAN - BOTTOM GILL NETS

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
100	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	1	2
110	0	0	0	5	1	2	0	0	0	4	1	10	0	31	0	3	0	0	2	55
120	0	1	0	10	0	6	0	10	0	3	2	11	0	29	2	9	0	0	4	79
130	0	1	0	1	1	0	0	0	0	1	1	3	0	3	0	1	0	0	2	10
140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
150	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
160	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
170	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2
TOTALS	0	2	0	16	2	8	0	10	0	8	5	24	0	67	2	16	0	0	9	151

Appendix 8. Continued.

YELLOW PERCH

LAKE MICHIGAN - SEINES

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
40	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0
50	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3	0
60	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	1	3
70	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1
80	0	0	0	0	0	0	0	0	0	0	0	1	0	12	0	0	0	0	0	13
90	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	7
100	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
110	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
TOTALS	0	0	0	0	0	0	0	0	3	4	4	2	0	20	0	0	0	0	7	26

LAKE MICHIGAN - TRAWLS

LENGTH INTERVAL	APR DAY	APR NGT	MAY DAY	MAY NGT	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
30	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
40	0	0	0	0	0	0	0	0	8	10	1	1	0	0	0	0	0	0	9	11
50	0	1	0	0	0	0	0	0	125	23	4	1	0	0	0	0	0	0	129	25
60	0	0	0	0	0	1	0	0	48	3	11	46	0	1	1	0	0	0	60	51
70	2	0	0	2	1	2	0	0	0	0	34	115	2	8	0	1	0	3	39	131
80	2	4	0	3	1	1	1	0	0	0	18	134	13	14	1	1	2	0	38	157
90	1	1	0	0	0	1	0	1	0	0	0	14	9	8	0	0	0	0	10	25
100	0	0	0	0	0	0	1	1	0	0	0	0	0	3	0	0	0	0	1	4
110	0	0	0	0	0	2	1	1	0	1	0	0	0	0	0	0	0	0	1	4
120	1	1	0	0	0	1	1	0	0	0	0	2	0	0	0	0	0	0	2	4
130	0	0	0	0	0	0	5	1	0	0	0	1	0	0	0	0	0	0	5	2
140	0	0	0	0	1	3	5	7	0	1	0	5	0	0	0	0	0	0	6	16
150	0	0	1	2	0	3	6	3	0	1	1	11	0	0	0	0	0	0	8	20
160	0	0	0	0	0	1	3	3	0	1	0	2	0	0	0	0	0	0	3	7
170	1	0	0	0	0	0	1	2	0	0	0	21	0	0	0	0	0	0	2	23
180	0	2	0	0	0	1	2	1	0	0	0	4	0	0	0	0	0	0	2	8
190	0	1	0	1	0	0	1	0	0	0	1	3	0	1	0	0	0	0	2	6
200	0	0	0	0	0	2	1	1	0	0	0	4	0	0	0	0	0	0	1	7
210	0	0	0	0	0	0	1	0	0	0	0	4	0	0	0	0	0	0	1	4
220	0	0	0	1	1	4	2	0	0	1	0	2	0	0	0	0	0	0	3	8
230	0	0	0	0	0	3	1	1	0	0	0	3	0	0	0	0	0	0	1	7
240	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2
250	0	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	1	3
270	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
TOTALS	7	10	1	9	4	25	34	24	191	43	70	376	24	35	2	2	2	3	325	527

Appendix 8. Continued.

YELLOW PERCH

LAKE MICHIGAN - BOTTOM GILL NETS

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
100	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	3	0
110	0	0	0	0	0	0	5	0	0	1	0	1	0	0	0	0	0	0	5	2
120	0	0	0	0	0	0	2	0	2	4	2	0	0	0	0	0	0	0	6	4
130	0	1	0	1	0	1	5	0	2	4	1	3	0	1	0	0	0	0	8	11
140	0	1	0	0	0	2	14	0	1	2	12	11	0	0	2	0	0	0	29	16
150	0	3	0	1	0	0	51	5	18	12	41	10	0	1	0	0	0	0	110	32
160	0	1	0	0	1	0	22	9	33	28	14	12	0	3	0	2	0	0	70	55
170	0	0	0	0	0	0	12	5	23	14	36	13	0	0	0	0	0	0	71	32
180	0	0	0	0	0	1	3	2	13	5	32	13	0	0	0	2	0	0	48	23
190	0	1	0	0	0	1	1	5	10	4	26	5	0	0	0	0	0	0	37	16
200	0	0	0	0	0	0	4	4	7	6	13	7	0	1	0	1	0	0	24	19
210	0	0	0	0	1	0	4	1	5	7	9	3	0	0	0	0	0	0	19	11
220	0	0	0	1	0	0	3	1	4	4	2	5	0	0	0	0	0	0	9	11
230	0	0	0	0	0	1	1	4	8	8	12	1	0	0	0	0	0	0	21	14
240	1	0	0	0	1	0	1	1	9	13	14	6	0	0	0	0	0	0	26	20
250	0	0	0	0	0	1	0	1	4	1	9	4	0	0	0	0	0	0	13	7
260	0	0	0	0	1	1	0	0	1	4	3	4	0	0	1	0	0	0	6	9
270	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2	1
280	0	0	0	0	0	0	1	0	2	1	3	3	0	0	0	0	0	0	6	4
290	0	0	0	0	0	0	0	1	2	1	2	0	0	1	0	0	0	0	4	3
300	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2
310	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	3
320	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
340	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	1	7	0	5	5	8	132	40	144	122	232	103	0	7	3	5	0	0	517	297

LAKE MICHIGAN - SURFACE GILL NETS.

LENGTH	APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
130	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
150	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
160	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
170	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	5
180	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
190	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
200	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3
210	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
TOTALS	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	16

Appendix 9. Number of fish larvae and eggs per 1000 m^3 for north transect stations in Lake Michigan near the J. H. Campbell Plant, April to September 1980. D = day, N = night, * = sled tow. See Appendix 1 for species code identification.

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	NS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
4-21-80	D	Q	0.5	10.3													0	0
4-21-80	D	Q	0.5	10.3						404							404	0
4-21-80	D	Q*	1.0	7.7													0	0
4-22-80	N	O	0.5	9.3						720							720	0
4-22-80	N	O	0.5	9.3						376							376	0
4-21-80	N	Q*	1.0	6.5													0	0
4-21-80	D	R	0.5	10.9													0	0
4-21-80	D	R	0.5	10.9													0	0
4-21-80	D	R*	1.0	9.0													0	0
4-22-80	N	R	0.5	9.6						459							459	0
4-22-80	N	R	0.5	9.6						711							711	0
4-21-80	N	R*	1.0	6.5													0	0
4-21-80	D	I	0.5	7.7													0	0
4-21-80	D	I*	1.5	7.0													0	0
4-21-80	N	I	0.5	6.7													0	0
4-21-80	N	I*	1.5	6.7													0	0
4-21-80	D	J	0.5	5.5													0	0
4-21-80	D	J	2.5	5.8													0	0
4-21-80	D	J*	3.0	5.8													0	0
4-22-80	N	J	0.5	6.0													0	0
4-21-80	N	J	2.5	6.5													0	0
4-21-80	N	J*	3.0	6.5													0	0
4-22-80	D	L	0.5	7.0													0	0
4-22-80	D	L	2.0	7.0													0	0
4-22-80	D	L	4.0	7.0													0	0
4-22-80	D	L	5.5	7.0													0	0
4-21-80	D	L*	6.0	5.1													0	0
4-22-80	N	L	0.5	5.2													0	0
4-22-80	N	L	2.0	5.2													0	0
4-22-80	N	L	4.0	5.2													0	0
4-22-80	N	L	5.5	5.2													0	0
4-21-80	N	L*	6.0	5.5													0	0

Appendix 9. Continued.

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	KC	TP	SS	NS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
4-22-80	D	N	0.5	6.0													0	0
4-22-80	D	N	2.5	6.1													0	0
4-22-80	D	N	4.5	6.0													0	0
4-22-80	D	N	6.5	5.8													0	0
4-22-80	D	N	8.5	5.3													0	0
4-21-80	D	N*	9.0	4.5													0	0
4-21-80	N	N	0.5	4.2													0	0
4-21-80	N	N	2.5	4.2													0	0
4-22-80	N	N	4.5	4.2													0	0
4-22-80	N	N	6.5	4.2													0	0
4-22-80	N	N	8.5	4.2													0	0
4-21-80	N	N*	9.0	4.5													0	0
4-22-80	D	O	0.5	4.5													0	0
4-22-80	D	O	3.0	4.5													0	0
4-22-80	D	O	6.0	4.5													0	0
4-22-80	D	O	9.0	4.6													0	0
4-22-80	D	O	11.0	4.6													0	0
4-21-80	D	O*	12.0	4.2													0	0
4-21-80	N	O	0.5	4.2													0	0
4-21-80	N	O	3.0	4.2													0	0
4-21-80	N	O	6.0	4.1													0	0
4-21-80	N	O	9.0	4.1													0	0
4-21-80	N	O	11.0	4.1													0	0
4-21-80	N	O*	12.0	4.5													0	0
4-22-80	D	W	0.5	3.0													0	0
4-22-80	D	W	4.5	3.0													0	0
4-22-80	D	W	8.5	3.1													0	0
4-22-80	D	W	11.5	3.1													0	0
4-22-80	D	W	14.0	3.1													0	0
4-21-80	D	W*	15.0	3.5													0	0
4-21-80	N	W	0.5	4.5													0	0
4-21-80	N	W	4.5	4.3													0	0
4-21-80	N	W	8.5	4.1													0	0
4-22-80	N	W	11.5	4.0													0	0
4-21-80	N	W	14.0	3.9													0	0
4-21-80	N	W*	15.0	4.5													0	0

Appendix 9. Continued.

DATE	DIEL PERIOD	STA-TION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	MS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
5-20-80	D	O	0.5	10.6													0	0
5-20-80	D	O	0.5	10.6			146										146	0
5-19-80	D	O*	1.0	10.9			456	65									521	130
5-20-80	N	O	0.5	10.3				277									277	0
5-20-80	N	O	0.5	10.3				147									147	0
5-19-80	N	O*	1.0	9.5			198	132									330	66
5-20-80	D	R	0.5	11.0			222									BR: 222	444	0
5-20-80	D	R	0.5	11.0				79									79	0
5-19-80	D	R*	1.0	10.9			386	257								BR: 64	707	64
5-20-80	N	R	0.5	11.0			479										479	0
5-20-80	N	R	0.5	11.0												BR: 843	843	421
5-19-80	N	R*	1.0	9.6			423									BR: 211	634	0
5-19-80	D	I	0.5	11.0			859	53									912	0
5-19-80	D	I*	1.5	10.0			414	828								BR: 248	1490	82
5-19-80	N	I	0.5	9.6			343	57									400	0
5-19-80	N	I*	1.5	9.6			74	74								BR: 74	222	0
5-19-80	D	J	0.5	9.0			114										114	0
5-19-80	D	J	2.5	9.0			265										265	0
5-19-80	D	J*	3.0	8.5			167	55									222	0
5-19-80	N	J	0.5	9.2			116										116	0
5-19-80	N	J	2.5	8.6			38										38	0
5-19-80	N	J*	3.0	8.6													0	0
5-20-80	D	L	0.5	9.0													0	0
5-20-80	D	L	2.0	8.9													0	0
5-20-80	D	L	4.0	7.8			83										83	0
5-20-80	D	L	5.5	6.9			28										28	0
5-19-80	D	L*	6.0	7.5													0	0
5-20-80	N	L	0.5	8.7			230										230	0
5-20-80	N	L	2.0	8.5			131										131	0
5-20-80	N	L	4.0	8.5			32										32	0
5-20-80	N	L	5.5	7.3			35										35	0
5-19-80	N	L*	6.0	7.3			56									BR: 28	84	0

Appendix 9. Continued.

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	NS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
5-20-80	D	N	0.5	10.1													0	0
5-20-80	D	N	2.5	10.2				21									21	0
5-20-80	D	N	4.5	9.3			92	15									107	0
5-20-80	D	N	6.5	7.1			59	19									78	0
5-20-80	D	N	8.5	6.8													0	0
5-19-80	D	N*	9.0	5.5													0	0
5-20-80	N	N	0.5	6.8													0	0
5-20-80	N	N	2.5	6.1			44										44	0
5-20-80	N	N	4.5	6.1			15										15	0
5-20-80	N	N	6.5	6.1													0	0
5-20-80	N	N	8.5	6.1													0	0
5-19-80	N	N*	9.0	6.1													0	0
5-20-80	D	O	0.5	10.4													0	0
5-20-80	D	O	3.0	10.0			14										14	0
5-20-80	D	O	6.0	8.2			66										66	0
5-20-80	D	O	9.0	6.8													0	0
5-20-80	D	O	11.0	6.3													0	0
5-19-80	D	O*	12.0	5.3													0	0
5-20-80	N	O	0.5	9.3													0	0
5-20-80	N	O	3.0	8.2													0	0
5-20-80	N	O	6.0	8.2													0	0
5-20-80	N	O	9.0	8.2													0	0
5-20-80	N	O	11.0	6.0													0	0
5-19-80	N	O*	12.0	6.0													0	0
5-20-80	D	W	0.5	10.3													0	0
5-20-80	D	W	4.5	8.9				26									26	0
5-20-80	D	W	8.5	8.2													0	0
5-20-80	D	W	11.5	7.3													0	0
5-20-80	D	W	14.0	6.0													0	0
5-19-80	D	W*	15.0	5.5													0	88
5-19-80	N	W	0.5	8.0													0	0
5-19-80	N	W	4.5	7.3												FS: 19	19	0
5-19-80	N	W	8.5	7.3													0	0
5-20-80	N	W	11.5	7.3													0	0
5-20-80	N	W	14.0	5.7			13										13	0
5-19-80	N	W*	15.0	5.7												FS: 45 LT: 45	90	0

Appendix 9. Continued.

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	MS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
6-03-80	D	Q	0.5	15.8													0	249
6-03-80	D	Q	0.5	15.8													0	0
6-03-80	D	Q*	1.0	15.7													0	704
6-04-80	N	Q	0.5	15.0													0	0
6-04-80	N	Q	0.5	15.0		305											305	0
6-04-80	N	Q*	1.0	13.5													0	26587
6-03-80	D	R	0.5	16.7													0	0
6-03-80	D	R	0.5	16.7													0	286
6-03-80	D	R*	1.0	16.7													0	235
6-03-80	N	R	0.5	15.7													0	336
6-03-80	N	R	0.5	15.7			330									ES: 330	660	0
6-03-80	N	R*	1.0	14.0		58											58	4811
6-04-80	D	I	0.5	11.2													0	0
6-04-80	D	I*	1.5	8.5													0	1361
6-03-80	N	I	0.5	14.0				217									217	0
6-03-80	N	I*	1.5	14.0													0	2647
6-04-80	D	J	0.5	11.0													0	0
6-04-80	D	J	2.5	11.0													0	0
6-04-80	D	J*	3.0	7.5													0	79
6-03-80	N	J	0.5	15.0													0	67
6-03-80	N	J	2.5	9.9													0	8888
6-03-80	N	J*	3.0	9.9													0	265
6-02-80	D	L	0.5	15.3													0	0
6-02-80	D	L	2.0	15.0													0	0
6-02-80	D	L	4.0	14.8													0	0
6-02-80	D	L	5.5	14.8	15		45										60	0
6-04-80	D	L*	6.0	7.3													0	466
6-04-80	N	L	0.5	9.8													0	0
6-04-80	N	L	2.0	7.7													0	2015
6-04-80	N	L	4.0	6.2													0	974
6-04-80	N	L	5.5	6.2													0	4103
6-03-80	N	L*	6.0	7.5													0	1511

Appendix 9. Continued.

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	KC	TP	SS	WS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
6-02-80	D	N	0.5	15.5													0	0
6-02-80	D	N	2.5	15.2													0	0
6-02-80	D	N	4.5	14.9			81										81	0
6-02-80	D	N	6.5	14.9			133										133	0
6-02-80	D	N	8.5	14.7			17										17	0
6-04-80	D	N*	9.0	6.5													0	70
6-04-80	N	N	0.5	13.9													0	60
6-04-80	N	N	2.5	8.1													0	0
6-04-80	N	N	4.5	7.1													0	3983
6-04-80	N	N	6.5	7.0													0	728
6-04-80	N	N	8.5	6.9													0	1471
6-03-80	N	N*	9.0	7.2													0	636
6-02-80	D	O	0.5	16.5													0	0
6-02-80	D	O	3.0	15.8													0	0
6-02-80	D	O	6.0	15.7			21										21	0
6-02-80	D	O	9.0	15.5			59										59	0
6-02-80	D	O	11.0	15.4			40										40	105
6-04-80	D	O*	12.0	6.3													0	0
6-04-80	N	O	0.5	13.0													0	0
6-04-80	N	O	3.0	8.0													0	364
6-04-80	N	O	6.0	6.4													0	456
6-04-80	N	O	9.0	6.4													0	270
6-04-80	N	O	11.0	6.4													0	352
6-03-80	N	O*	12.0	7.0													0	355
6-02-80	D	W	0.5	16.8													0	0
6-02-80	D	W	4.5	16.6	21		124										145	0
6-02-80	D	W	8.5	16.5	13		26										39	0
6-02-80	D	W	11.5	16.4	28	14											42	28
6-02-80	D	W	14.0	16.1			14									GS: 14	28	0
6-04-80	D	W*	15.0	6.1												GS: 33	33	0
6-04-80	N	W	0.5	13.8													0	0
6-04-80	N	W	4.5	7.0													0	0
6-04-80	N	W	8.5	5.7													0	60
6-04-80	N	W	11.5	5.7													0	0
6-04-80	N	W	14.0	5.6													0	51
6-03-80	N	W*	15.0	6.3													0	47

Appendix 9. Continued.

DATE	DIEL PERIOD	STA-TION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	KC	TP	SS	WS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
6-16-80	D	Q	0.5	14.5													0	2601
6-16-80	D	Q	0.5	14.5	114												114	1141
6-16-80	D	Q*	1.0	13.0		80											80	20740
6-17-80	N	Q	0.5	11.0	180	1173											1353	1716
6-17-80	N	Q	0.5	11.0	269	2153			134								2556	7676
6-17-80	N	Q*	1.0	11.0	97	194	388									GS: 97	776	4367
6-16-80	D	R	0.5	15.5													0	260
6-16-80	D	R	0.5	15.5													0	0
6-16-80	D	R*	1.0	13.0	242			242						242			726	2755186
6-17-80	N	R	0.5	11.5	645	647											1292	485
6-17-80	N	R	0.5	11.5	673	337											1010	168
6-17-80	N	R*	1.0	11.5													0	1033
6-16-80	D	T	0.5	13.0													0	1682
6-16-80	D	T*	1.5	12.5		69											69	70738
6-17-80	N	T	0.5	11.5		235	117										352	0
6-17-80	N	T*	1.5	11.5													0	5682
6-16-80	D	J	0.5	10.7													0	0
6-16-80	D	J	2.5	10.7													0	0
6-16-80	D	J*	3.0	10.7			132										132	5030
6-16-80	N	J	0.5	11.5													0	0
6-17-80	N	J	2.5	9.0		67											67	0
6-16-80	N	J*	3.0	9.0													0	112
6-17-80	D	L	0.5	13.0													0	0
6-17-80	D	L	2.0	12.9													0	0
6-17-80	D	L	4.0	12.3	23		23										46	0
6-17-80	D	L	5.5	11.5													0	484
6-16-80	D	L*	6.0	8.3			89										89	624
6-18-80	N	L	0.5	14.2	22										22		44	0
6-18-80	N	L	2.0	14.2													0	0
6-18-80	N	L	4.0	14.2													0	0
6-18-80	N	L	5.5	14.1													0	0
6-16-80	N	L*	6.0	7.3													0	46209

Appendix 9. Continued.

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	NUMBER OF LARVAE PER 1000 M³: AL	SP	SM	YP	JD	XC	TP	SS	NS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
6-17-80	D	N	0.5	13.2													0	0
6-17-80	D	N	2.5	13.0												GS: 20	20	0
6-17-80	D	N	4.5	11.1			40										40	0
6-17-80	D	N	6.5	10.8			59										59	0
6-17-80	D	N	8.5	10.3			22										22	0
6-16-80	D	N*	9.0	7.4			28										28	0
6-18-80	N	N	0.5	14.4		43		21				21					85	0
6-18-80	N	N	2.5	14.3	40			20				40					100	0
6-18-80	N	N	4.5	14.2	14	28											42	0
6-18-80	N	N	6.5	13.9		36		17								GS: 17	70	0
6-18-80	N	N	8.5	13.9	42	43				14							99	0
6-16-80	N	N*	9.0	6.8													0	129
6-17-80	D	O	0.5	13.0			14										14	0
6-17-80	D	O	3.0	12.8	88												88	C
6-17-80	D	O	6.0	11.0	52		35								17	GS: 17	121	0
6-17-80	D	O	9.0	8.7			42									BR: 21	63	0
6-17-80	D	O	11.0	8.6	14												14	0
6-16-80	D	O*	12.0	6.7			44										44	0
6-18-80	N	O	0.5	14.7		18						37					55	0
6-18-80	N	O	3.0	14.5	77	15						15					107	0
6-18-80	N	O	6.0	14.0	36	37		18				18					109	0
6-18-80	N	O	9.0	13.8		16	15	15				15					61	0
6-18-80	N	O	11.0	13.8	38		18										56	0
6-16-80	N	O*	12.0	6.8			29										29	59
6-17-80	D	W	0.5	13.0													0	0
6-17-80	D	W	4.5	12.5			43										43	14
6-17-80	D	W	8.5	10.0	60		19										79	0
6-17-80	D	W	11.5	8.8	26		12										38	0
6-17-80	D	W	14.0	13.7			17										17	0
6-16-80	D	W*	15.0	7.3			22										22	0
6-18-80	N	W	0.5	14.8	45												45	0
6-18-80	N	W	4.5	14.8			36	18								BR: 18	72	0
6-18-80	N	W	8.5	13.8	17		52										69	0
6-18-80	N	W	11.5	13.7			61										61	0
6-18-80	N	W	14.0	13.0			15										15	0
6-16-80	N	W*	15.0	6.3													0	133

Appendix 9. Continued.

DATE	DIEL PERIOD	STA-TION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	NS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
7-01-80	D	Q	0.5	18.4	275												275	0
7-01-80	D	Q	0.5	18.4	1777												1777	296
7-01-80	D	Q*	1.0	18.4	5290	460											5750	920
7-01-80	N	Q	0.5	17.3	4620	20791											25411	0
7-01-80	N	Q	0.5	17.3		7639											7639	1054
7-01-80	N	Q*	1.0	17.0	2196	1791											3987	5808
7-01-80	D	R	0.5	18.7	2240												2240	1120
7-01-80	D	R	0.5	18.7	2524	504											3028	0
7-01-80	D	R*	1.0	18.7	13595	453											14048	4985
7-01-80	N	R	0.5	16.9	6171	15016											21187	617
7-01-80	N	R	0.5	16.9	8060	4960											13020	10852
7-01-80	N	R*	1.0	16.1	1539	4124											5663	83
7-01-80	D	I	0.5	17.1	1915			35									1950	426
7-01-80	D	I*	1.5	17.1	9587	4941											14528	55897
7-01-80	N	I	0.5	17.7	1512	396											1908	216
7-01-80	N	I*	1.5	16.5	803	949	73										1825	146
7-01-80	D	J	0.5	16.6	282												282	0
7-01-80	D	J	2.5	16.6	3133												3133	45
7-01-80	D	J*	3.0	17.0	984												984	123
7-01-80	N	J	0.5	17.6	1692			51							51		1794	0
7-01-80	N	J	2.5	16.0	3283	270	29	29									3611	663
7-01-80	N	J*	3.0	16.0	1010	392	56										1458	1800
7-01-80	D	L	0.5	18.8	2104	52		17									2173	0
7-01-80	D	L	2.0	18.8	7330			58									7388	29
7-01-80	D	L	4.0	18.7	8407	51											8458	0
7-01-80	D	L	5.5	18.7	12034	21											12055	21
7-01-80	D	L*	6.0	16.2	506						46						552	1058
7-02-80	N	L	0.5	21.0	4693	148		469									5310	0
7-02-80	N	L	2.0	21.0	3502	141		100								GS: 20	3763	0
7-02-80	N	L	4.0	20.9	3636	127		54								BS: 54	3871	0
7-02-80	N	L	5.5	20.9	3145	111		37									3293	56
7-01-80	N	L*	6.0	13.5	233	33					100						366	2267

Appendix 9. Continued.

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	KC	TP	SS	MS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M^3	TOTAL NUMBER OF EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3													
7-01-80	D	N	0.5	19.2	218												218	0
7-01-80	D	N	2.5	19.0	5072			20									5092	0
7-01-80	D	N	4.5	18.9	6072												6072	0
7-01-80	D	N	6.5	18.8	17852			78							19		17949	0
7-01-80	D	N	8.5	18.8	4171	52											4223	0
7-01-80	D	N*	9.0	15.9	1336								55				1391	223
7-02-80	N	N	0.5	21.2	3914	54		187									4155	0
7-02-80	N	N	2.5	21.1	13768	293		34	34								14129	0
7-02-80	N	N	4.5	21.0	8272	264											8536	0
7-02-80	N	N	6.5	20.8	11320	1094		23									12437	0
7-02-80	N	N	8.5	20.7	17410	9794											27204	0
7-01-80	N	N*	9.0	13.2	295			42	42		127	42	42				590	42
7-01-80	D	O	0.5	19.3	735												735	0
7-01-80	D	O	3.0	19.1	14313			20									14333	0
7-01-80	D	O	6.0	18.8	5979			49									6028	0
7-01-80	D	O	9.0	18.3	4574												4574	0
7-01-80	D	O	11.0	18.2	4977												4977	95
7-01-80	D	O*	12.0	15.6	1660												1660	692
7-01-80	N	O	0.5	21.1	5880	149		33									6062	0
7-01-80	N	O	3.0	20.7	3742	209		77									4028	0
7-02-80	N	O	6.0	20.5	2888	1242			65							XL: 32	4227	0
7-02-80	N	O	9.0	20.4	1313	371		19								GS: 19	1722	0
7-02-80	N	O	11.0	20.4	5312	934			52					26			6324	55
7-01-80	N	O*	12.0	13.5	1757						36	146	36	36			2011	36
7-01-80	D	W	0.5	20.5	531												531	0
7-01-80	D	W	4.5	20.4	3996			19							19		4034	0
7-01-80	D	W	8.5	19.2	2899										22		2921	0
7-01-80	D	W	11.5	18.5	9527		26	52									9605	0
7-01-80	D	W	14.0	17.2	1991												1991	0
7-01-80	D	W*	15.0	13.3	1009	31											1040	1580
7-01-80	N	W	0.5	21.2	3155	38		308									3501	0
7-01-80	N	W	4.5	20.6	2067	115		91							22		2295	0
7-01-80	N	W	8.5	20.2	559	177											736	0
7-01-80	N	W	11.5	17.7	552	91											643	0
7-01-80	N	W	14.0	17.5	149	24				12							185	0
7-01-80	N	W*	15.0	12.4	183				20		41	164					408	143

Appendix 9. Continued.

DATE	DIEL PERIOD	STA-TION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	MS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
7-14-80	D	Q	0.5	22.2	4263	213											4476	0
7-14-80	D	Q	0.5	22.2	2133	213											2346	213
7-15-80	D	Q*	1.0	22.5	5040	2772											7812	1362994
7-14-80	N	Q	0.5	21.4	4290	9136											13426	9408
7-14-80	N	Q	0.5	21.4	1876	3223											5099	3225
7-15-80	N	Q*	1.0	22.0	617	441											1058	9622
7-14-80	D	R	0.5	22.6	11023	917											11940	0
7-14-80	D	R	0.5	22.6	8266	1606											9872	0
7-15-80	D	R*	1.0	22.5	18093	9652										ES: 301	28046	228665
7-14-80	N	R	0.5	21.6	3867	8085											11952	1186
7-14-80	N	R	0.5	21.6	2709	3654											6363	522
7-15-80	N	R*	1.0	22.2	66	99		11									176	93254
7-15-80	D	I	0.5	22.3	4715	152											4867	13219
7-15-80	D	I*	1.5	22.0	1857	10034											11891	198063
7-15-80	N	I	0.5	22.5	8772	2969											11741	0
7-15-80	N	I*	1.5	22.5	581	4362											4943	1769572
7-14-80	D	J	0.5	22.5	6474	181											6655	0
7-14-80	D	J	2.5	22.0	2508												2508	0
7-15-80	D	J*	3.0	22.0	6490	2456											8946	243189
7-15-80	N	J	0.5	22.5	4374	171											4545	0
7-15-80	N	J	2.5	21.5	4726	27											4753	0
7-15-80	N	J*	3.0	21.0	1906	565											2471	3475
7-14-80	D	L	0.5	22.4	224	80											304	0
7-14-80	D	L	2.0	22.4	998												998	43
7-14-80	D	L	4.0	22.3	1554												1554	21
7-14-80	D	L	5.5	22.3	3724	52											3776	503
7-15-80	D	L*	6.0	20.8	6485	484			40								7009	79499
7-15-80	N	L	0.5	25.1	2599	32											2631	10127
7-15-80	N	L	2.0	25.1	3987	103											4090	19274
7-15-80	N	L	4.0	25.1	7615	50			24								7689	4957
7-15-80	N	L	5.5	25.1	5700	17											5717	3958
7-15-80	N	L*	6.0	21.0	1498	74			37		37						1646	4826

Appendix 9. Continued

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	MS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M^3	TOTAL NUMBER OF EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3													
7-14-80	D	N	0.5	22.5	55												55	0
7-14-80	D	N	2.5	22.4	1140	16											1156	0
7-14-80	D	N	4.5	22.0	1925			16						16			1957	0
7-14-80	D	N	6.5	21.9	2681												2681	0
7-14-80	D	N	8.5	21.8	4171												4171	0
7-15-80	D	N*	9.0	20.4	1898	388							173				2459	2942
7-15-80	N	N	0.5	25.0	1184	16		16	16								1232	0
7-15-80	N	N	2.5	25.0	763	58		14	57								892	0
7-15-80	N	N	4.5	25.0	1194	20											1214	0
7-15-80	N	N	6.5	24.9	1462	22											1484	0
7-15-80	N	N	8.5	24.9	1847			22									1869	0
7-16-80	N	N*	9.0	21.0	1020	63			87		109			43			1322	788
7-14-80	D	O	0.5	22.5	80	16											96	0
7-14-80	D	O	3.0	22.0	1289			22									1311	0
7-14-80	D	O	6.0	21.5	509												509	0
7-14-80	D	O	9.0	21.1	441												441	0
7-14-80	D	O	11.0	21.1	288	24											312	0
7-15-80	D	O*	12.0	20.1	294												294	0
7-14-80	N	O	0.5	25.3	1191	15											1206	0
7-14-80	N	O	3.0	25.3	1358	75		15	15								1463	45
7-14-80	N	O	6.0	24.8	1224												1224	0
7-14-80	N	O	9.0	23.9	1033	33											1066	0
7-15-80	N	O	11.0	23.5	914	60			29								1003	0
7-16-80	N	O*	12.0	21.0	544	206			12								762	48
7-14-80	D	W	0.5	21.3	1609	178								16			1803	0
7-14-80	D	W	4.5	21.2	1860	17		17									1894	0
7-14-80	D	W	8.5	21.1	540												540	0
7-14-80	D	W	11.5	21.1	168												168	0
7-14-80	D	W	14.0	21.0													0	0
7-15-80	D	W*	15.0	20.3	111												111	0
7-14-80	N	W	0.5	25.1	1385	32		16		16							1449	0
7-14-80	N	W	4.5	25.1	2960	48											3008	0
7-14-80	N	W	8.5	24.3	2377	19											2396	0
7-14-80	N	W	11.5	22.0	213	71											284	0
7-14-80	N	W	14.0	20.0	333	333											666	0
7-16-80	N	W*	15.0	20.5	404				21								425	0

Appendix 9. Continued.

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	NS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
8-05-80	D	Q	0.5	24.0	1141												1141	6190
8-05-80	D	Q	0.5	24.0	935												935	4767
8-04-80	D	Q*	1.0	22.0	5584	24815								310			30709	397741
8-04-80	N	Q	0.5	23.7	1941	277											2218	0
8-04-80	N	Q	0.5	23.7	9523	2116											11639	0
8-05-80	N	Q*	1.0	23.3	198	3762								33			3993	2540
8-05-80	D	R	0.5	24.5	1773												1773	0
8-05-80	D	R	0.5	24.5	520											ES: 104	624	104
8-04-80	D	R*	1.0	22.5	868	476											1344	282
8-04-80	N	R	0.5	24.5		37573											37573	1212
8-04-80	N	R	0.5	24.5	1776	8885											10661	0
8-05-80	N	R*	1.0	23.3	4644	13236											17880	2555
8-04-80	D	I	0.5	22.0	85												85	0
8-04-80	D	I*	1.5	22.0	131												131	0
8-04-80	N	I	0.5	24.4	1589	72			36								1697	0
8-05-80	N	I*	1.5	24.4	1374	6083											7457	0
8-04-80	D	J	0.5	22.0													0	0
8-04-80	D	J	2.5	21.5	59												59	0
8-04-80	D	J*	3.0	21.5	134												134	0
8-05-80	N	J	0.5	23.3	1911	26											1937	0
8-05-80	N	J	2.5	23.3	1244												1244	0
8-05-80	N	J*	3.0	23.3	732	122			122								976	367
8-05-80	D	L	0.5	23.0	278												278	0
8-05-80	D	L	2.0	23.0	1464												1464	0
8-05-80	D	L	4.0	22.9	2055												2055	0
8-05-80	D	L	5.5	22.9	1271												1271	0
8-04-80	D	L*	6.0	21.8													0	386
8-06-80	N	L	0.5	22.0	563	22											585	0
8-06-80	N	L	2.0	22.0	1151												1151	0
8-06-80	N	L	4.0	22.0	1443	10											1453	0
8-06-80	N	L	5.5	21.9	1116						8						1124	0
8-04-80	N	L*	6.0	23.0		401											401	0

Appendix 9. Continued.

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	MS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
8-05-80	D	N	0.5	23.0													0	12
8-05-80	D	N	2.5	22.9	758												758	0
8-05-80	D	N	4.5	22.7	401												401	0
8-05-80	D	N	6.5	22.5	765												765	0
8-05-80	D	N	8.5	22.5	798												798	0
8-04-80	D	N*	9.0	21.5													0	0
8-06-80	N	N	0.5	22.2	132	12									24		168	0
8-06-80	N	N	2.5	22.2	298				9								307	0
8-06-80	N	N	4.5	22.2	230												230	0
8-06-80	N	N	6.5	22.2	274												274	0
8-06-80	N	N	8.5	22.1	404												404	0
8-05-80	N	N*	9.0	22.8	336				1688		337						2361	337
8-05-80	D	O	0.5	23.5													0	0
8-05-80	D	O	3.0	23.3	278												278	0
8-05-80	D	O	6.0	23.2	277												277	0
8-05-80	D	O	9.0	23.1	484												484	0
8-05-80	D	O	11.0	22.9	259												259	0
8-04-80	D	O*	12.0	20.7	64												64	0
8-06-80	N	O	0.5	22.5	161												161	0
8-06-80	N	O	3.0	22.3	190												190	0
8-06-80	N	O	6.0	22.1	291	15			15								321	0
8-06-80	N	O	9.0	21.9	133												133	0
8-06-80	N	O	11.0	21.9	96	19											115	0
8-05-80	N	O*	12.0	24.0	178						89						267	0
8-05-80	D	W	0.5	23.5													0	0
8-05-80	D	W	4.5	23.5	71												71	0
8-05-80	D	W	8.5	23.5													0	0
8-05-80	D	W	11.5	23.3	16												16	0
8-05-80	D	W	14.0	23.2													0	0
8-04-80	D	W*	15.0	10.5													0	0
8-05-80	N	W	0.5	22.0	40												40	0
8-05-80	N	W	4.5	22.0	45												45	0
8-05-80	N	W	8.5	21.9	75												75	0
8-05-80	N	W	11.5	21.9	191												191	0
8-05-80	N	W	14.0	21.3	161												161	0
8-05-80	N	W*	15.0	18.0	89												89	0

Appendix 9. Continued.

DATE	DIEL PERIOD	STA-TION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	MS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
8-19-80	D	Q	0.5	21.0													0	0
8-19-80	D	O	0.5	21.0													0	0
8-18-80	D	Q*	1.0	20.0	156	312											468	0
8-20-80	N	Q	0.5	22.5													0	0
8-20-80	N	O	0.5	22.5													0	0
8-18-80	N	O*	1.0	19.3		328											328	0
8-19-80	D	R	0.5	21.3													0	0
8-19-80	D	P	0.5	21.3													0	0
8-18-80	D	R*	1.0	20.0		1652											1652	0
8-20-80	N	P	0.5	22.7		218											218	0
8-20-80	N	R	0.5	22.7	505												505	0
8-18-80	N	R*	1.0	18.5		4179											4179	0
8-18-80	D	I	0.5	19.3	26												26	0
8-18-80	D	I*	1.5	19.3	118	118											236	0
8-18-80	N	I	0.5	20.0	142												142	0
8-18-80	N	I*	1.5	18.5		2367											2367	0
8-18-80	D	J	0.5	19.5	24												24	0
8-18-80	D	J	2.5	18.6	72												72	0
8-18-80	D	J*	3.0	18.6		32											32	0
8-18-80	N	J	0.5	20.5	47												47	0
8-18-80	N	J	2.5	17.0	87												87	0
8-18-80	N	J*	3.0	17.0													0	0
8-18-80	D	L	0.5	20.0													0	0
8-18-80	D	L	2.0	19.8	16												16	0
8-18-80	D	L	4.0	19.1	48												48	0
8-18-80	D	L	5.5	18.4	46												46	0
8-18-80	D	L*	6.0	16.5													0	0
8-20-80	N	L	0.5	19.0	144												144	0
8-20-80	N	L	2.0	19.0	81												81	0
8-19-80	N	L	4.0	17.0	56												56	0
8-18-80	N	L	5.5	16.0	55												55	0
8-18-80	N	L*	6.0	16.7					312								312	0

Appendix 9. Continued.

DATE	DIEL PERIOD	STA-TION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	KC	TP	SS	MS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
8-18-80	D	N	0.5	20.0													0	0
8-18-80	D	N	2.5	19.9	70												70	0
8-18-80	D	N	4.5	19.3	64												64	0
8-18-80	D	N	6.5	18.2	15												15	0
8-18-80	D	N	8.5	17.7	28												28	0
8-18-80	D	N*	9.0	15.5													0	0
8-18-80	N	N	0.5	19.0	154												154	0
8-18-80	N	N	2.5	18.9	74												74	0
8-18-80	N	N	4.5	17.8	105												105	0
8-18-80	N	N	6.5	15.5	80											ES: 33	113	0
8-18-80	N	N	8.5	13.5	17												17	0
8-18-80	N	N*	9.0	15.3					625								625	0
8-18-80	D	O	0.5	20.8													0	0
8-18-80	D	O	3.0	20.5	63									9			72	0
8-18-80	D	O	6.0	19.9	40												40	0
8-18-80	D	O	9.0	18.5	48												48	0
8-18-80	D	O	11.0	18.1	90												90	0
8-18-80	D	O*	12.0	15.0													0	0
8-18-80	N	O	0.5	19.0	102												102	0
8-18-80	N	O	3.0	18.9	89												89	0
8-18-80	N	O	6.0	18.0	122												122	0
8-18-80	N	O	9.0	16.4													0	0
8-18-80	N	O	11.0	12.5													0	0
8-18-80	N	O*	12.0	10.6					61								61	0
8-18-80	D	W	0.5	20.9													0	0
8-18-80	D	W	4.5	20.1	195												195	0
8-18-80	D	W	8.5	18.9													0	0
8-18-80	D	W	11.5	17.1	104												104	0
8-18-80	D	W	14.0	11.8	32												32	0
8-18-80	D	W*	15.0	9.0													0	0
8-18-80	N	W	0.5	20.0	80												80	0
8-18-80	N	W	4.5	19.3	28												28	0
8-18-80	N	W	8.5	17.3	28												28	0
8-18-80	N	W	11.5	12.0	17												17	0
8-18-80	N	W	14.0	7.8													0	0
8-18-80	N	W*	15.0	7.8					77				38				115	0

Appendix 9. Continued.

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	NUMBER OF LARVAE PER 1000 M^3												TOTAL NUMBER OF LARVAE PER 1000 M^3	TOTAL NUMBER OF EGGS PER 1000 M^3
					AL	SP	SM	YP	JD	XC	TP	SS	MS	XP	CP	MISC.		
9-18-80	D	Q	0.5	12.7													0	0
9-18-80	D	Q	0.5	12.7													0	0
9-15-80	D	Q*	1.0	18.5													0	0
9-15-80	N	Q	0.5	16.3													0	0
9-15-80	N	Q	0.5	16.3													0	0
9-15-80	N	Q*	1.0	16.3		64					64						128	0
9-18-80	D	R	0.5	12.7													0	0
9-18-80	D	R	0.5	12.7													0	0
9-15-80	D	R*	1.0	18.0		84											84	0
9-15-80	N	R	0.5	16.5													0	0
9-15-80	N	R	0.5	16.5													0	0
9-15-80	N	R*	1.0	16.5													0	0
9-15-80	D	I	0.5	19.0													0	0
9-15-80	D	I*	1.5	19.0													0	0
9-15-80	N	I	0.5	16.5													0	0
9-15-80	N	I*	1.5	16.0					87								87	0
9-15-80	D	J	0.5	18.0													0	0
9-15-80	D	J	2.5	17.0													0	0
9-15-80	D	J*	3.0	17.0	48												48	0
9-15-80	N	J	0.5	16.4													0	0
9-15-80	N	J	2.5	14.5													0	0
9-15-80	N	J*	3.0	14.5													0	0
9-15-80	D	L	0.5	16.9													0	0
9-15-80	D	L	2.0	16.8													0	0
9-15-80	D	L	4.0	14.5													0	0
9-15-80	D	L	5.5	13.7													0	0
9-15-80	D	L*	6.0	15.0													0	0
9-15-80	N	L	0.5	19.2													0	0
9-15-80	N	L	2.0	19.2	14												14	0
9-16-80	N	L	4.0	18.8													0	0
9-16-80	N	L	5.5	18.2													0	0
9-15-80	N	L*	6.0	15.7					26								26	0

Appendix 9. Continued.

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	WS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M^3	TOTAL NUMBER OF EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3													
9-15-80	D	N	0.5	18.0													0	0
9-15-80	D	N	2.5	17.5													0	0
9-15-80	D	N	4.5	15.9													0	0
9-15-80	D	N	6.5	13.3													0	0
9-15-80	D	N	8.5	12.8													0	0
9-15-80	D	N*	9.0	12.2													0	0
9-15-80	N	N	0.5	19.8													0	0
9-15-80	N	N	2.5	19.8													0	0
9-15-80	N	N	4.5	19.7											16		16	0
9-15-80	N	N	6.5	19.0	20												28	0
9-15-80	N	N	8.5	18.3	20												20	0
9-15-80	N	N*	9.0	14.1													0	0
9-15-80	D	O	0.5	18.0													0	0
9-15-80	D	O	3.0	17.4													0	0
9-15-80	D	O	6.0	14.7													0	0
9-15-80	D	O	9.0	11.2													0	0
9-15-80	D	O	11.0	11.0													0	0
9-15-80	D	O*	12.0	11.0													0	0
9-15-80	N	O	0.5	18.1													0	0
9-15-80	N	O	3.0	18.1													0	0
9-15-80	N	O	6.0	18.1													0	0
9-15-80	N	O	9.0	17.3													0	0
9-15-80	N	O	11.0	15.2													0	0
9-15-80	N	O*	12.0	9.7													0	0
9-15-80	D	W	0.5	20.0													0	0
9-15-80	D	W	4.5	19.7													0	0
9-15-80	D	W	8.5	14.7													0	0
9-15-80	D	W	11.5	9.7													0	0
9-15-80	D	W	14.0	9.2													0	0
9-15-80	D	W*	15.0	10.0													0	0
9-15-80	N	W	0.5	18.1													0	0
9-15-80	N	W	4.5	18.0													0	0
9-15-80	N	W	8.5	18.0													0	0
9-15-80	N	W	11.5	13.5													0	0
9-15-80	N	W	14.0	9.0													0	0
9-15-80	N	W*	15.0	7.5													0	0

Appendix 10. Number of fish larvae and eggs per 1000 m^3 for south transect stations in Lake Michigan near the J. H. Campbell Plant, April to September 1980. D = day, N = night, * = sled tow. See Appendix 1 for species code identification.

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	NUMBER OF LARVAE PER 1000 M3 AL	SP	SM	YP	JD	XC	TP	SS	NS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M3	TOTAL NUMBER OF EGGS PER 1000 M3
4-22-80	D	P	0.5	12.3						229							229	0
4-21-80	D	P	0.5	12.3													0	0
4-21-80	D	P*	1.0	8.5													0	0
4-22-80	N	P	0.5	12.0						1415							1415	0
4-22-80	N	P	0.5	12.0						1413							1413	0
4-21-80	N	P*	1.0	7.6						49							49	0
4-21-80	D	A*	1.5	7.0													0	0
4-21-80	N	A	0.5	7.5													0	0
4-21-80	N	A*	1.5	7.5													0	0
4-21-80	D	B	0.5	6.9													0	0
4-21-80	D	B	2.5	6.9													0	0
4-21-80	D	B*	3.0	6.9													0	0
4-21-80	N	B	0.5	6.7						24							24	0
4-21-80	N	B	2.5	6.7													0	0
4-21-80	N	B*	3.0	6.7													0	0
4-22-80	D	C	0.5	7.0													0	0
4-22-80	D	C	2.0	7.0													0	0
4-22-80	D	C	4.0	6.9													0	0
4-22-80	D	C	5.5	6.9													0	0
4-21-80	D	C*	6.0	5.6													0	0
4-21-80	N	C	0.5	6.0													0	0
4-21-80	N	C	2.0	6.0													0	0
4-21-80	N	C	4.0	6.0													0	0
4-21-80	N	C	5.5	5.8													0	0
4-21-80	N	C*	6.0	6.0													0	0
4-22-80	D	D	0.5	4.5													0	0
4-22-80	D	D	2.5	4.5													0	0
4-22-80	D	D	4.5	4.4													0	0
4-22-80	D	D	6.5	4.4													0	0
4-22-80	D	D	8.5	4.4													0	0
4-21-80	D	D*	9.0	5.0													0	0
4-21-80	N	D	0.5	4.5													0	0
4-21-80	N	D	2.5	4.5												PS: 12 RR: 12	24	0
4-21-80	N	D	4.5	4.4													0	0
4-21-80	N	D	6.5	4.4													0	0
4-21-80	N	D	8.5	4.4												PS: 32	32	0
4-21-80	N	D*	9.0	5.2													0	0

Appendix 10. Continued.

DATE	DIEL PERIOD	STA-TION	DEPTH (M)	TEMP. C	AL	SP	SN	YP	JD	XC	TP	SS	NS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
4-22-80	D	E	0.5	4.5													0	0
4-22-80	D	E	3.0	4.5													0	0
4-22-80	D	E	6.0	4.4													0	0
4-22-80	D	E	9.0	4.4													0	0
4-22-80	D	E	11.0	4.4						11							11	0
4-21-80	D	E*	12.0	4.8													0	0
4-21-80	N	E	0.5	4.2													0	0
4-21-80	N	E	3.0	4.2												FS: 15	15	0
4-21-80	N	E	6.0	4.3													0	0
4-21-80	N	E	9.0	4.4													0	0
4-21-80	N	E	11.0	4.4													0	0
4-21-80	N	E*	12.0	4.5													0	0
4-22-80	D	F	0.5	4.0													0	0
4-22-80	D	F	4.5	4.0													0	0
4-22-80	D	F	8.5	4.0													0	0
4-22-80	D	F	11.5	4.0													0	0
4-22-80	D	F	14.0	4.0													0	0
4-21-80	D	F*	15.0	4.6													0	0
4-21-80	N	F	0.5	3.5													0	0
4-21-80	N	F	4.5	3.5													0	0
4-21-80	N	F	8.5	4.1													0	0
4-21-80	N	F	11.5	4.1													0	0
4-21-80	N	F	14.0	4.1													0	0
4-21-80	N	F*	15.0	4.0													0	0
5-20-80	D	P	0.5	9.0													0	0
5-20-80	D	P	0.5	9.0													0	0
5-19-80	D	P*	1.0	11.4				44									44	0
5-19-80	N	P	0.5	10.5												BP: 202	202	0
5-20-80	N	P	0.5	10.5			606	404								BP: 202	1212	0
5-19-80	N	P*	1.0	9.1			59	178									237	0
5-19-80	D	A	0.5	10.0													0	0
5-19-80	D	A*	1.5	10.0				345								BF: 69	414	0
5-19-80	N	A	0.5	9.3				3030									3030	0
5-19-80	N	A*	1.5	8.2												BF: 106	106	0

Appendix 10. Continued.

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	NS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
5-19-80	D	B	0.5	9.6													0	0
5-19-80	D	B	2.5	9.6													0	0
5-19-80	D	B*	3.0	9.6												BR: 36	36	0
5-19-80	N	B	0.5	8.3												BR: 31	31	0
5-19-80	N	B	2.5	7.2													0	0
5-19-80	N	B*	3.0	7.2													0	0
5-20-80	D	C	0.5	9.0													0	0
5-20-80	D	C	2.0	8.2													0	0
5-20-80	D	C	4.0	7.4													0	0
5-20-80	D	C	5.5	5.8													0	0
5-19-80	D	C*	6.0	7.8													0	0
5-19-80	N	C	0.5	10.5													0	0
5-19-80	N	C	2.0	10.4													0	0
5-19-80	N	C	4.0	9.7			49										49	0
5-19-80	N	C	5.5	9.2			74									BR: 37	111	0
5-19-80	N	C*	6.0	6.9													0	0
5-20-80	D	D	0.5	10.5													0	0
5-20-80	D	D	2.5	9.5													0	0
5-20-80	D	D	4.5	8.0													0	0
5-20-80	D	D	6.5	6.5													0	0
5-20-80	D	D	8.5	6.5													0	0
5-19-80	D	D*	9.0	7.5													0	0
5-19-80	N	D	0.5	7.8													0	0
5-19-80	N	D	2.5	7.7													0	0
5-19-80	N	D	4.5	7.5													0	0
5-19-80	N	D	6.5	6.2													0	0
5-19-80	N	D	8.5	5.3													0	0
5-19-80	N	D*	9.0	6.1													0	0
5-20-80	D	E	0.5	9.5													0	0
5-20-80	D	E	3.0	8.3			23										23	0
5-20-80	D	E	6.0	5.2													0	0
5-20-80	D	E	9.0	5.1													0	0
5-20-80	D	E	11.0	5.1													0	0
5-19-80	D	E*	12.0	6.4													0	0
5-19-80	N	E	0.5	8.5												BR: 16	16	0
5-19-80	N	E	3.0	8.4													0	0
5-19-80	N	E	6.0	8.4													0	0
5-19-80	N	E	9.0	8.4													0	0
5-19-80	N	E	11.0	5.5													0	0
5-19-80	N	E*	12.0	5.5													0	0

Appendix 10. Continued.

DATE	DIEL PERIOD	STA-TION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	KC	TP	SS	NS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
5-20-80	D	F	0.5	10.2													0	0
5-20-80	D	F	4.5	9.6													0	0
5-20-80	D	F	8.5	6.6													0	0
5-20-80	D	F	11.5	5.8													0	0
5-20-80	D	F	14.0	5.7													0	0
5-19-80	D	F*	15.0	5.5													0	0
5-19-80	N	F	0.5	8.6													0	0
5-19-80	N	F	4.5	6.6													0	0
5-19-80	N	F	8.5	6.6													0	0
5-19-80	N	F	11.5	6.6												PS: 12	12	0
5-19-80	N	F	14.0	5.2													0	0
5-19-80	N	F*	15.0	5.2													0	0
6-02-80	D	P	0.5	16.8													0	0
6-02-80	D	P	0.5	16.8													0	0
6-02-80	D	P*	1.0	16.5												PM: 76	76	6790
6-04-80	N	P	0.5	13.8													0	0
6-04-80	N	P	0.5	13.8													0	0
6-04-80	N	P*	1.0	11.5													0	610
6-02-80	D	A	0.5	15.7													0	0
6-02-80	D	A*	1.5	15.1													0	0
6-03-80	N	A	0.5	15.5													0	0
6-03-80	N	A*	1.5	13.3													0	666
6-02-80	D	B	0.5	15.5													0	0
6-02-80	D	B	2.5	14.9													0	0
6-02-80	D	B*	3.0	14.9													0	0
6-03-80	N	B	0.5	15.5													0	0
6-03-80	N	B	2.5	10.5			141										141	0
6-03-80	N	B*	3.0	10.5													0	134
6-02-80	D	C	0.5	14.2													0	0
6-02-80	D	C	2.0	14.1													0	69
6-02-80	D	C	4.0	14.1													0	0
6-02-80	D	C	5.5	14.0													0	0
6-02-80	D	C*	6.0	14.2													0	3278
6-03-80	N	C	0.5	14.3													0	0
6-03-80	N	C	2.0	14.3					32							BR: 32	64	487
6-03-80	N	C	4.0	9.0													0	889
6-03-80	N	C	5.5	9.0													0	0
6-03-80	N	C*	6.0	8.6													0	1529

Appendix 10. Continued.

DATE	DIEL PERIOD	STA-TION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	NS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
6-02-80	D	D	0.5	14.0													0	0
6-02-80	D	D	2.5	13.9													0	0
6-02-80	D	D	4.5	13.8													0	171
6-02-80	D	D	6.5	13.7													0	0
6-02-80	D	D	8.5	13.6													0	0
6-02-80	D	D*	9.0	14.0													0	1749
6-03-80	N	D	0.5	13.9													0	0
6-03-80	N	D	2.5	9.3													0	0
6-03-80	N	D	4.5	8.1													0	414
6-03-80	N	D	6.5	8.0													0	282
6-03-80	N	D	8.5	7.9													0	0
6-03-80	N	D*	9.0	7.3													0	874
6-02-80	D	E	0.5	15.0													0	0
6-02-80	D	E	3.0	14.8													0	0
6-02-80	D	E	6.0	14.8													0	0
6-02-80	D	E	9.0	14.7													0	0
6-02-80	D	E	11.0	14.6			13										13	0
6-03-80	D	E*	12.0	14.0													0	468
6-03-80	N	E	0.5	13.9			16										16	0
6-03-80	N	E	3.0	8.3			36										36	0
6-03-80	N	E	6.0	7.1													0	0
6-03-80	N	E	9.0	6.9													0	0
6-03-80	N	E	11.0	6.9												BP: 27	27	0
6-03-80	N	E*	12.0	6.7													0	1347
6-02-80	D	F	0.5	15.0													0	0
6-02-80	D	F	4.5	14.9			26										26	0
6-02-80	D	F	8.5	14.7			14										14	0
6-02-80	D	F	11.5	14.6													0	0
6-02-80	D	F	14.0	14.6			31										31	0
6-02-80	D	F*	15.0	13.5													0	48
6-03-80	N	F	0.5	13.9													0	0
6-03-80	N	F	4.5	8.9													0	0
6-03-80	N	F	8.5	6.6													0	0
6-03-80	N	F	11.5	6.5													0	0
6-03-80	N	F	14.0	6.4													0	0
6-03-80	N	F*	15.0	6.5													0	302

Appendix 10. Continued.

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	NS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
6-16-80	D	P	0.5	15.0													0	0
6-16-80	D	P	0.5	15.0	115												115	115
6-16-80	D	P*	1.0	13.0	358										575		933	62824
6-16-80	N	P	0.5	10.5		180											180	722
6-16-80	N	P	0.5	10.5	142	284	142										568	0
6-17-80	N	P*	1.0	10.5	62												62	1189
6-16-80	D	A	0.5	13.0	137	27											164	0
6-16-80	D	A*	1.5	13.0	267		107	53									427	32122
6-17-80	N	A	0.5	10.5	29	29	29										87	291
6-17-80	N	A*	1.5	10.5													0	7531
6-16-80	D	B	0.5	10.7	25												25	207
6-16-80	D	B	2.5	10.5													0	0
6-16-80	D	B*	3.0	10.5	40		122										162	5111
6-16-80	N	B	0.5	11.0	58	29	58										145	0
6-17-80	N	B	2.5	9.5	54		53										107	54
6-16-80	N	B*	3.0	9.5													0	164
6-17-80	D	C	0.5	13.6													0	0
6-17-80	D	C	2.0	13.5													0	0
6-17-80	D	C	4.0	13.3													0	0
6-17-80	D	C	5.5	13.2													0	23
6-16-80	D	C*	6.0	10.0													0	4437
6-17-80	N	C	0.5	12.3													0	154
6-17-80	N	C	2.0	12.3													0	70
6-17-80	N	C	4.0	12.3													0	49
6-17-80	N	C	5.5	12.3													0	1177
6-16-80	N	C*	6.0	8.5	60		30										90	91
6-17-80	D	D	0.5	13.7													0	0
6-17-80	D	D	2.5	13.3													0	0
6-18-80	D	D	4.5	13.2			25										25	0
6-17-80	D	D	6.5	12.9			51										51	0
6-17-80	D	D	8.5	12.1	28												28	0
6-16-80	D	D*	9.0	8.5	35												35	35
6-17-80	N	D	0.5	12.4													0	0
6-17-80	N	D	2.5	12.4													0	0
6-17-80	N	D	4.5	12.4													0	0
6-17-80	N	D	6.5	12.3													0	0
6-17-80	N	D	8.5	11.8	21												21	0
6-16-80	N	D*	9.0	7.5			22										22	110

Appendix 10. Continued.

DATE	DIEL PERIOD	STA-TION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	NS	YP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M3	TOTAL NUMBER OF EGGS PER 1000 M3
					NUMBER OF LARVAE PER 1000 M3													
6-17-80	D	E	0.5	13.3													0	0
6-17-80	D	E	3.0	12.2						27							27	0
6-17-80	D	E	6.0	11.4	46												46	0
6-17-80	D	E	9.0	10.7			48										48	0
6-17-80	D	E	11.0	10.7													0	0
6-16-80	D	E*	12.0	8.5													0	0
6-17-80	N	E	0.5	13.0													0	0
6-17-80	N	E	3.0	13.0			23										23	0
6-17-80	N	E	6.0	11.6			22										22	0
6-17-80	N	E	9.0	9.9													0	0
6-17-80	N	E	11.0	9.6			34										34	0
6-16-80	N	E*	12.0	7.0			23										23	138
6-17-80	D	F	0.5	14.0													0	0
6-17-80	D	F	4.5	12.4			62										62	0
6-17-80	D	F	8.5	9.6			26										26	0
6-17-80	D	F	11.5	8.9													0	0
6-17-80	D	F	14.0	8.8			22										22	23
6-16-80	D	F*	15.0	7.5													0	79
6-17-80	N	F	0.5	13.0			75										75	0
6-17-80	N	F	4.5	12.2			94										94	0
6-17-80	N	F	8.5	10.0													0	0
6-17-80	N	F	11.5	8.1			69										69	0
6-17-80	N	F	14.0	7.9			19										19	0
6-16-80	N	F*	15.0	6.5													0	38
7-01-80	D	P	0.5	18.6	634	317											951	0
7-01-80	D	P	0.5	18.6	404									404			808	0
7-01-80	D	P*	1.0	18.6	3220	920											4140	5980
7-01-80	N	P	0.5	17.3	6189	87613											93802	1428
7-01-80	N	P	0.5	17.3	8331	31661											39992	5666
7-01-80	N	P*	1.0	16.5	2870	260		18									3148	1419
7-01-80	D	A	0.5	17.6	152												152	304
7-01-80	D	A*	1.5	17.6	4105	1224	61										5390	5213
7-01-80	N	A	0.5	17.0	2845												2845	11636
7-01-80	N	A*	1.5	15.3	288	432											720	10391

Appendix 10. Continued.

DATE	DIEL PERIOD	STA-TION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	NS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
7-01-80	D	B	0.5	17.6	50												50	0
7-01-80	D	B	2.5	17.5	1433												1433	260
7-01-80	D	B*	3.0	17.4	2852												2852	7315
7-01-80	N	B	0.5	17.0	3700			64									3764	161
7-01-80	N	B	2.5	15.3	3534			122									3656	1507
7-01-80	N	B*	3.0	15.3	2579												2579	6451
7-01-80	D	C	0.5	19.8	1938												1938	0
7-01-80	D	C	2.0	19.8	3118			55									3173	56
7-01-80	D	C	4.0	19.8	3592			60									3652	0
7-01-80	D	C	5.5	19.8	4928	18	18	18									4982	73
7-01-80	D	C*	6.0	16.6	802	33											835	100
7-01-80	N	C	0.5	21.0	13103	21		605							21		13750	43
7-01-80	N	C	2.0	21.0	8869	86		34									8989	0
7-01-80	N	C	4.0	20.9	11946	1613											13559	0
7-01-80	N	C	5.5	20.9	21828	66		16									21910	0
7-01-80	N	C*	6.0	14.9	3990	35								70			4095	175
7-01-80	D	D	0.5	19.5	7222											GS: 21	7243	0
7-01-80	D	D	2.5	19.5	2510												2510	0
7-01-80	D	D	4.5	19.5	1476			24									1500	0
7-01-80	D	D	6.5	19.4	1395			19									1414	0
7-01-80	D	D	8.5	19.4	937												937	0
7-01-80	D	D*	9.0	16.4	105												105	0
7-01-80	N	D	0.5	20.8	20393	212		373									20978	0
7-01-80	N	D	2.5	20.8	11749	165								20			11934	0
7-01-80	N	D	4.5	20.8	8238	206		41									8485	0
7-01-80	N	D	6.5	20.7	3548	108		17									3673	18
7-01-80	N	D	8.5	20.7	2358	161											2519	0
7-01-80	N	D*	9.0	13.7	114												114	38
7-01-80	D	E	0.5	19.3	2014												2014	0
7-01-80	D	E	3.0	19.3	1990			77									2067	0
7-01-80	D	E	6.0	19.3	1176			53									1229	0
7-01-80	D	E	9.0	19.2	1481			30									1511	0
7-01-80	D	E	11.0	19.2	1216			77									1293	0
7-01-80	D	E*	12.0	16.5	545	68											613	239
7-01-80	N	E	0.5	20.8	12723	93		94									12910	0
7-01-80	N	E	3.0	20.7	1410	48											1458	0
7-01-80	N	E	6.0	20.6	2300	46		22					22	22			2412	0
7-01-80	N	E	9.0	20.6	1154	44								21			1219	0
7-01-80	N	E	11.0	20.6	3750		20										3770	0
7-01-80	N	E*	12.0	13.1	3301	44											3345	4534

Appendix 10. Continued.

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	AL	SP	SH	YP	JD	KC	TP	SS	NS	KP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
7-01-80	D	P	0.5	19.5													0	0
7-01-80	D	P	4.5	19.5	1544			178									1722	0
7-01-80	D	P	8.5	19.5	1235			218									1453	0
7-01-80	D	P	11.5	19.4	555												555	0
7-01-80	D	P	14.0	18.0	264			27									291	0
7-01-80	D	P*	15.0	13.9	32			65									97	1505
7-02-80	N	P	0.5	20.5	5303	19		76					38				5436	0
7-01-80	N	P	4.5	20.4	449	26											475	0
7-01-80	N	P	8.5	20.3	1007			114									1121	0
7-01-80	N	P	11.5	19.2	168												168	0
7-01-80	N	P	14.0	17.8	315			88									403	0
7-01-80	N	P*	15.0	12.6	182							137					319	2609
7-14-80	D	P	0.5	22.4	3713	655											4368	0
7-14-80	D	P	0.5	22.4	8300	218											8518	0
7-15-80	D	P*	1.0	22.8	5070	361											5431	20473
7-14-80	N	P	0.5	22.6	7868	25318								238			33424	0
7-14-80	N	P	0.5	22.6	10673	18824											29497	0
7-14-80	N	P*	1.0	22.5	4478	3220											7698	492
7-15-80	D	A	0.5	22.8	3628	66											3694	0
7-15-80	D	A*	1.5	22.6	4764	393											5157	32073
7-15-80	N	A	0.5	23.0	2851	478											3329	0
7-14-80	N	A*	1.5	22.5	4094	3661											7755	621
7-15-80	D	B	0.5	22.8	2558												2558	0
7-15-80	D	B	2.5	22.0	4685	60											4745	0
7-15-80	D	B*	3.0	22.0	116	731								29			976	1439
7-15-80	N	B	0.5	22.8	5220	322											5542	0
7-15-80	N	B	2.5	22.8	1724	819											2543	0
7-14-80	N	B*	3.0	21.5	5538	3308											8846	4782
7-14-80	D	C	0.5	23.0	16554	20											16574	0
7-14-80	D	C	2.0	22.9	2712	17											2729	0
7-14-80	D	C	4.0	22.9	1505			47									1552	0
7-14-80	D	C	5.5	22.9	1210	22		34						11			1277	0
7-15-80	D	C*	6.0	20.9	889												989	1782
7-14-80	N	C	0.5	25.8	2262	40											2302	0
7-14-80	N	C	2.0	25.8	3027	36											3963	0
7-14-80	N	C	4.0	25.6	2206												2206	0
7-14-80	N	C	5.5	25.5	1854	42											1896	0
7-14-80	N	C*	6.0	21.5	780												780	6133

Appendix 10. Continued.

DATE	DIEL PERIOD	STA-TION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	NS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M3	TOTAL NUMBER OF EGGS PER 1000 M3
					NUMBER OF LARVAE PER 1000 M3													
7-14-80	D	D	0.5	22.9	2101	19											2120	0
7-14-80	D	D	2.5	22.5	957	17											974	0
7-14-80	D	D	4.5	22.5	494												494	0
7-14-80	D	D	6.5	22.4	717			16									733	0
7-14-80	D	D	8.5	22.4	477												477	0
7-15-80	D	D*	9.0	20.8	690	43											733	43
7-14-80	N	D	0.5	25.2	1102	100											1202	0
7-14-80	N	D	2.5	25.2	1824	19											1843	0
7-14-80	N	D	4.5	25.0	2853												2853	0
7-14-80	N	D	6.5	24.5	2588			17									2605	0
7-14-80	N	D	8.5	23.5	2170	23											2193	0
7-14-80	N	D*	9.0	21.0	910				57								967	29
7-14-80	D	E	0.5	22.8	6828	21								42			6891	0
7-14-80	D	E	3.0	22.4	755												755	0
7-14-80	D	E	6.0	22.3	342												342	0
7-14-80	D	E	9.0	22.1	362												362	0
7-14-80	D	E	11.0	22.1	573												573	16
7-15-80	D	E*	12.0	20.8	204	872			51								1127	102
7-14-80	N	E	0.5	25.6	720												720	0
7-14-80	N	E	3.0	25.5	1443	57											1500	0
7-14-80	N	E	6.0	25.2	2921	61							20				3002	0
7-14-80	N	E	9.0	22.3	1139	34											1173	0
7-14-80	N	E	11.0	22.1	400	75											475	0
7-15-80	N	E*	12.0	21.0	159	106			267			53	267				852	53
7-14-80	D	F	0.5	22.5	19												19	0
7-14-80	D	F	4.5	22.3	1061												1061	0
7-14-80	D	F	8.5	21.6	329												329	0
7-14-80	D	F	11.5	20.1	255												255	0
7-14-80	D	F	14.0	15.5	546												546	0
7-15-80	D	F*	15.0	13.7													0	0
7-14-80	N	F	0.5	25.2	1696	80		16						16			1908	0
7-14-80	N	F	4.5	25.0	1252	77											1329	0
7-14-80	N	F	8.5	22.3	700	51											751	0
7-14-80	N	F	11.5	20.8	627												627	0
7-14-80	N	F	14.0	17.5	118												118	0
7-15-80	N	F*	15.0	21.0	399	44											443	0

Appendix 10. Continued.

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	NS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M3	TOTAL NUMBER OF EGGS PER 1000 M3
					NUMBER OF LARVAE PER 1000 M3													
8-05-80	D	P	0.5	23.6	103	103											206	413
8-05-80	D	P	0.5	23.6	136												136	409
8-04-80	D	P*	1.0	24.0	55	496											551	55
8-04-80	N	P	0.5	24.5	2016	1344								224			3584	0
8-04-80	N	P	0.5	24.5	1540	2695											4235	0
8-06-80	N	P*	1.0	22.5	16100	50600								2300			69000	9200
8-04-80	D	A	0.5	23.7													0	0
8-04-80	D	A*	1.5	23.5	2242	572			52				52			PS: 156	3074	13644
8-05-80	N	A	0.5	22.7	1559												1559	0
8-05-80	N	A*	1.5	22.5	2508	9196											11704	0
8-04-80	D	B	0.5	24.0	96												96	0
8-04-80	D	B	2.5	23.9	120												120	0
8-04-80	D	B*	3.0	23.9		264											264	1213
8-05-80	N	B	0.5	22.5	665											PS: 83	748	83
8-05-80	N	B	2.5	22.5	1712	162			80								1954	0
8-05-80	N	B*	3.0	22.5	5256	9199											14455	17087
8-05-80	D	C	0.5	24.3	289									12			301	0
8-05-80	D	C	2.0	24.3	450												450	0
8-05-80	D	C	4.0	24.3	80												80	0
8-05-80	D	C	5.5	24.3	36												36	0
8-04-80	D	C*	6.0	23.7	24												24	0
8-05-80	N	C	0.5	22.2	215	11											226	0
8-05-80	N	C	2.0	22.2	185												185	0
8-05-80	N	C	4.0	22.2	998												998	0
8-05-80	N	C	5.5	22.2	529												529	0
8-05-80	N	C*	6.0	22.5	558				155								713	124
8-05-80	D	D	0.5	24.0	20												20	0
8-05-80	D	D	2.5	23.9	121												121	0
8-05-80	D	D	4.5	23.9	135												135	0
8-05-80	D	D	6.5	23.9	169												169	0
8-05-80	D	D	8.5	23.7	68												68	0
8-04-80	D	D*	9.0	18.0	54												54	0
8-05-80	N	D	0.5	22.3	74				12					12			98	0
8-05-80	N	D	2.5	22.3	147												147	0
8-05-80	N	D	4.5	22.3	172												172	0
8-05-80	N	D	6.5	22.3	158												158	0
8-05-80	N	D	8.5	22.3	417						17						434	0
8-05-80	N	D*	9.0	22.5	165				828								993	0

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Appendix 10. Continued.

DATE	DIEL PERIOD	STA-TION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	NS	KP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
8-18-80	D	P	0.5	20.7	11												11	0
8-18-80	D	P	4.5	19.3	30												30	0
8-18-80	D	P	8.5	15.3	64												64	0
8-18-80	D	P	11.5	9.7	22												22	0
8-18-80	D	P	14.0	7.4													0	0
8-18-80	D	P*	15.0	7.4													0	0
8-18-80	N	P	0.5	19.3	31												31	0
8-18-80	N	P	4.5	18.5	11												11	0
8-18-80	N	P	8.5	14.9	39												39	0
8-18-80	N	P	11.5	9.8	16												16	0
8-18-80	N	P	14.0	9.1													0	0
8-18-80	N	P*	15.0	8.4					59			29					88	0
9-18-80	D	P	0.5	12.7													0	0
9-15-80	D	P	0.5	12.7													0	0
9-15-80	D	P*	1.0	17.4													0	0
9-15-80	N	P	0.5	18.2													0	0
9-15-80	N	P	0.5	18.2													0	0
9-15-80	N	P*	1.0	18.2													0	0
9-15-80	D	A	0.5	16.9													0	0
9-15-80	D	A*	1.5	16.6	162												162	0
9-15-80	N	A	0.5	18.0													0	0
9-15-80	N	A*	1.5	18.0	25												25	0
9-15-80	D	B	0.5	16.7													0	0
9-15-80	D	B	2.5	14.7													0	0
9-15-80	D	B*	3.0	14.7													0	0
9-15-80	N	B	0.5	18.5													0	0
9-15-80	N	B	2.5	17.5													0	0
9-15-80	N	B*	3.0	17.5							22						22	0
9-15-80	D	C	0.5	16.9													0	0
9-15-80	D	C	2.0	16.9	15												15	0
9-15-80	D	C	4.0	16.2													0	0
9-15-80	D	C	5.5	15.4	13												13	0
9-15-80	D	C*	6.0	12.7													0	0
9-15-80	N	C	0.5	17.0	15												15	0
9-15-80	N	C	2.0	17.0													0	0
9-15-80	N	C	4.0	16.0													0	0
9-15-80	N	C	5.5	13.4													0	0
9-15-80	N	C*	6.0	16.9													0	0

Appendix 10. Continued.

DATE	DIEL PERIOD	STA-TION	DEPTH (M)	TEMP. C	AL	SP	SM	YP	JD	XC	TP	SS	NS	XP	CP	MISC.	TOTAL NUMBER OF LARVAE PER 1000 M³	TOTAL NUMBER OF EGGS PER 1000 M³
					NUMBER OF LARVAE PER 1000 M³													
9-15-80	D	D	0.5	17.0													0	0
9-15-80	D	D	2.5	16.8													0	0
9-15-80	D	D	4.5	15.0													0	0
9-15-80	D	D	6.5	11.0													0	0
9-15-80	D	D	8.5	8.8													0	0
9-15-80	D	D*	9.0	10.2													0	0
9-15-80	N	D	0.5	18.5													0	0
9-15-80	N	D	2.5	18.5													0	0
9-15-80	N	D	4.5	18.2													0	0
9-15-80	N	D	6.5	16.5													0	0
9-15-80	N	D	8.5	10.5													0	0
9-15-80	N	D*	9.0	9.9													0	0
9-15-80	D	E	0.5	17.0													0	0
9-15-80	D	E	3.0	17.0													0	0
9-15-80	D	E	6.0	12.4													0	0
9-15-80	D	E	9.0	8.5													0	0
9-15-80	D	E	11.0	7.8													0	0
9-15-80	D	E*	12.0	8.8													0	0
9-15-80	N	E	0.5	17.3													0	0
9-15-80	N	E	3.0	17.3													0	0
9-15-80	N	E	6.0	17.2													0	0
9-15-80	N	E	9.0	10.0													0	0
9-15-80	N	E	11.0	8.1													0	0
9-15-80	N	E*	12.0	8.0													0	0
9-15-80	D	F	0.5	18.0													0	0
9-15-80	D	F	4.5	17.8													0	0
9-15-80	D	F	8.5	10.1													0	0
9-15-80	D	F	11.5	8.1													0	0
9-15-80	D	F	14.0	7.5													0	0
9-15-80	D	F*	15.0	7.5													0	0
9-15-80	N	F	0.5	17.2													0	0
9-15-80	N	F	4.5	17.2													0	0
9-15-80	N	F	8.5	16.6													0	0
9-15-80	N	F	11.5	7.4													0	0
9-15-80	N	F	14.0	6.8													0	0
9-15-80	N	F*	15.0	6.7													0	0

Appendix 11. Number of fish fry per 1000 m^3 caught during fish larvae sampling near the J. H. Campbell Plant, eastern Lake Michigan, April to September 1980. D = day, N = night, * = sled tow. See Appendix 1 for species code identification.

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	SM	SP	AL	YP	TP	JD	MS	XC	LT	ES	SS	WS	MISC.	TOTAL NUMBER OF FRY PER 1000 M^3
					NUMBER OF FRY PER 1000 M^3													
4-21-80	N	F	11.0	4.4	11													11
4-21-80	N	O*	12.0	4.5									134					134
4-21-80	N	W*	15.0	4.5									39					39
5-19-80	N	D*	9.0	6.1					56	28								84
5-19-80	N	F*	15.0	5.2					31									31
5-19-80	N	J*	3.0	8.6						70			70					140
5-19-80	N	L*	6.0	7.3	282	28					28							338
5-19-80	D	N*	9.0	5.5									79					79
5-19-80	N	N*	9.0	6.1					38				38					76
5-20-80	N	O	11.0	6.0	22													22
5-19-80	N	W*	15.0	5.7									45					45
6-03-80	N	C	0.5	14.3	14													14
6-03-80	N	F	4.5	8.9	26													26
6-03-80	N	F*	15.0	6.5					30									30
6-04-80	N	L	2.0	7.7	48													48
6-03-80	N	L*	6.0	7.5					68									68
6-03-80	N	N*	9.0	7.2					106									106
6-17-80	N	A	0.5	10.5		29												29
6-17-80	N	C	5.5	12.3	20		20											40
6-17-80	N	D	6.5	12.3			25											25
6-17-80	N	F	14.0	7.9	19													19
6-17-80	N	O	0.5	11.0			134											134
6-17-80	N	O*	1.0	11.0	97		194											291
6-18-80	N	L	5.5	14.1			14											14
6-17-80	D	O	3.0	12.8			22											22
6-17-80	D	O	11.0	8.6			14											14

Appendix 11. Continued.

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	SM	SP	AL	YP	TP	JD	MS	XC	LT	BS	SS	WS	MISC.	TOTAL NUMBER OF FRY PER 1000 M³
					NUMBER OF FRY PER 1000 M³													
7-01-80	N	P*	1.0	16.5	18													18
7-01-80	N	A*	1.5	15.3	72													72
7-01-80	D	D	6.5	19.4	19													19
7-01-80	N	D*	9.0	13.7	38													38
7-01-80	N	J*	3.0	16.0	619													619
7-01-80	N	L*	6.0	13.5					133									133
7-01-80	D	W	11.5	18.5	26													26
7-01-80	N	W	4.5	20.6	22													22
7-01-80	N	W	8.5	20.2	24													24
7-14-80	N	C	5.5	25.5	14													14
7-14-80	N	D*	9.0	21.0	28													28
7-14-80	D	L	2.0	22.4			14											14
7-15-80	N	L	0.5	25.1	16													16
7-15-80	N	L	5.5	25.1					17									17
7-15-80	N	L*	6.0	21.0	75													75
7-15-80	D	N*	9.0	20.4	43													43
7-16-80	N	N*	9.0	21.0	43													43
7-16-80	N	W*	15.0	20.5	21													21
8-05-80	D	C	0.5	24.3			12											12
8-05-80	N	C	2.0	22.2	21		31											52
8-05-80	N	C	4.0	22.2			18											18
8-05-80	N	C	5.5	22.2	11		22											33
8-05-80	N	D	2.5	22.3			11											11
8-05-80	N	D	4.5	22.3			19											19
8-05-80	N	D	6.5	22.3			34											34
8-05-80	N	D	8.5	22.3	17		34											51
8-05-80	N	E	3.0	23.0			9											9
8-05-80	N	E	9.0	22.9			146											146
8-05-80	N	E	11.0	22.8			31											31
8-04-80	D	F*	15.0	10.4	26													26
8-05-80	N	F	0.5	22.5			23											23
8-05-80	N	F	4.5	22.4			46											46
8-05-80	N	F	11.5	21.9			15											15

Appendix 11. Continued.

DATE	DIEL PERIOD	STA-TION	DEPTH (M)	TEMP. C	SM	SP	AL	YP	TP	JD	MS	YC	LT	ES	SS	WS	MISC.	TOTAL NUMBER OF FRY PER 1000 M³
					NUMBER OF FRY PER 1000 M³													
8-04-80	N	Q	0.5	23.7			1058											1058
8-05-80	N	Q*	1.0	23.3	33													33
8-05-80	N	I*	1.5	24.4		786												786
8-05-80	N	J*	3.0	23.3		244												244
8-06-80	N	L	2.0	22.0	10		51											61
8-06-80	N	L	4.0	22.0			20											20
8-06-80	N	L	5.5	21.9			71											71
8-06-80	N	N	2.5	22.2			18											18
8-06-80	N	N	4.5	22.2			30											30
8-06-80	N	N	6.5	22.2			18											18
8-06-80	N	N	8.5	22.1			40											40
8-05-80	D	O	0.5	23.5			11											11
8-05-80	D	O	3.0	23.3	12													12
8-04-80	D	W*	15.0	10.5	38													38
8-05-80	N	W	8.5	21.9			15											15
8-05-80	N	W	14.0	21.3			19											19
8-05-80	N	W*	15.0	18.0	89													89
8-18-80	N	P*	1.0	20.8	374	213		53										640
8-18-80	N	A*	1.5	21.0	447	471		49										967
8-18-80	D	B*	3.0	18.9	2407													2407
8-18-80	N	B	2.5	17.2	32													32
8-18-80	N	B*	3.0	17.2	2760	394		43										3197
8-18-80	N	B*	3.0	16.0	376													376
8-18-80	D	C	2.0	18.0	11													11
8-18-80	D	C	5.5	13.6	79													79
8-18-80	N	C	0.5	19.0	33													33
8-18-80	N	C	2.0	19.0	44													44
8-18-80	N	C	4.0	18.4	232		90											322
8-18-80	N	C	5.5	17.0	76		38											114
8-18-80	D	D	0.5	20.0	23													23
8-18-80	D	D	2.5	19.0	30													30
8-18-80	D	D	8.5	10.8	21													21
8-18-80	N	D	0.5	19.5			16											16
8-18-80	N	D	4.5	18.1	15		31											46
8-18-80	N	D	8.5	15.8	17													17
8-19-80	N	D*	9.0	14.3	952													952
8-18-80	N	E	0.5	19.3	16													16
8-18-80	N	F*	12.0	10.6	168													168
8-18-80	N	F	4.5	18.5	11													11
8-18-80	N	F	11.5	9.8				16										16
8-18-80	N	F*	15.0	8.4	207													207

DATE	DIEL PERIOD	STATION	DEPTH (M)	TEMP. C	NUMBER OF FRY PER 1000 M³													TOTAL NUMBER OF FRY PER 1000 M³
					SM	SP	AL	YP	TP	JD	WS	XC	LT	BS	SS	WS	MISC.	
8-20-80	N	Q	0.5	22.5			343											343
8-18-80	D	R*	1.0	20.0		663												663
8-18-80	N	R*	1.0	18.5		929												929
8-18-80	N	I*	1.5	18.5	215	1079												1294
8-18-80	N	J*	3.0	17.0	6900													6900
8-18-80	N	J*	3.0	16.7	6885													6885
8-20-80	N	L	0.5	19.0			12											12
8-20-80	N	L	2.0	19.0	301		18											319
8-19-80	N	L	4.0	17.0			58											58
8-18-80	N	L	5.5	16.0	231		44											275
8-18-80	N	M	0.5	19.0	33													33
8-18-80	N	M	2.5	18.9	109		39											148
8-18-80	N	M	4.5	17.8	15		30											45
8-18-80	N	M	6.5	15.5	82		66											148
8-18-80	N	M	8.5	13.5	17													17
8-18-80	N	M*	9.0	15.3	876													876
8-18-80	D	O	0.5	19.0	17		34											51
8-18-80	N	O	3.0	18.9	34		46											80
8-18-80	N	O	6.0	18.0	15		62											77
8-18-80	N	O	9.0	16.4	17		17											34
8-18-80	N	O	11.0	12.5	100													100
8-18-80	N	O*	12.0	10.6	246													246
8-18-80	D	W	0.5	20.9	12													12
8-18-80	D	W*	15.0	9.0	51													51
8-18-80	N	W	0.5	20.0			16											16
8-18-80	N	W	4.5	19.3	14													14
8-18-80	N	W	11.5	12.0	16													16
8-18-80	N	W	14.0	7.8	144													144
8-18-80	N	W*	15.0	7.8	464						38							502
9-15-80	N	P	0.5	18.2		311												311
9-15-80	N	P*	1.0	18.2	28	1452				28								1508
9-15-80	N	A	0.5	18.0	20													20
9-15-80	N	A*	1.5	18.0	204													204
9-15-80	N	B*	3.0	17.5	113	22												135
9-15-80	N	C	0.5	17.0								15						15
9-15-80	N	C	5.5	13.4			30					15						45
9-15-80	N	D	2.5	18.5			44											44
9-15-80	N	D	6.5	16.5	19							19						38
9-15-80	N	D	8.5	10.5	19													19
9-15-80	N	D*	9.0	10.5	31					31								62
9-15-80	N	E	3.0	17.3			16											16
9-15-80	N	E	6.0	17.2			19											19
9-15-80	N	E	11.0	8.1	18													18
9-15-80	N	E*	12.0	8.1	28													28
9-15-80	N	E	14.0	6.8	32													32
9-15-80	N	E*	15.0	6.8	43													43

Appendix 11. Continued.

DATE	DIEL PERIOD	STA- TION	DEPTH (M)	TEMP. C	SM	SP	AL	YP	TP	JD	MS	KC	LT	ES	SS	WS	MISC.	TOTAL NUMBER OF FRY PER 1000 M³
					NUMBER OF FRY PER 1000 M³													
9-15-80	N	O*	1.0	16.3	129	774				64								967
9-15-80	N	I*	1.5	16.0	263	877				263								1403
9-15-80	N	J	0.5	16.4	27													27
9-15-80	N	J*	3.0	14.5	106	919				35								1060
9-16-80	N	L	4.0	18.8			21											21
9-15-80	N	O	6.0	18.1	15		15											30
9-15-80	N	O*	12.0	9.7	17													17
9-15-80	N	W	0.5	18.1			14											14
9-15-80	N	W	14.0	9.0	18													18